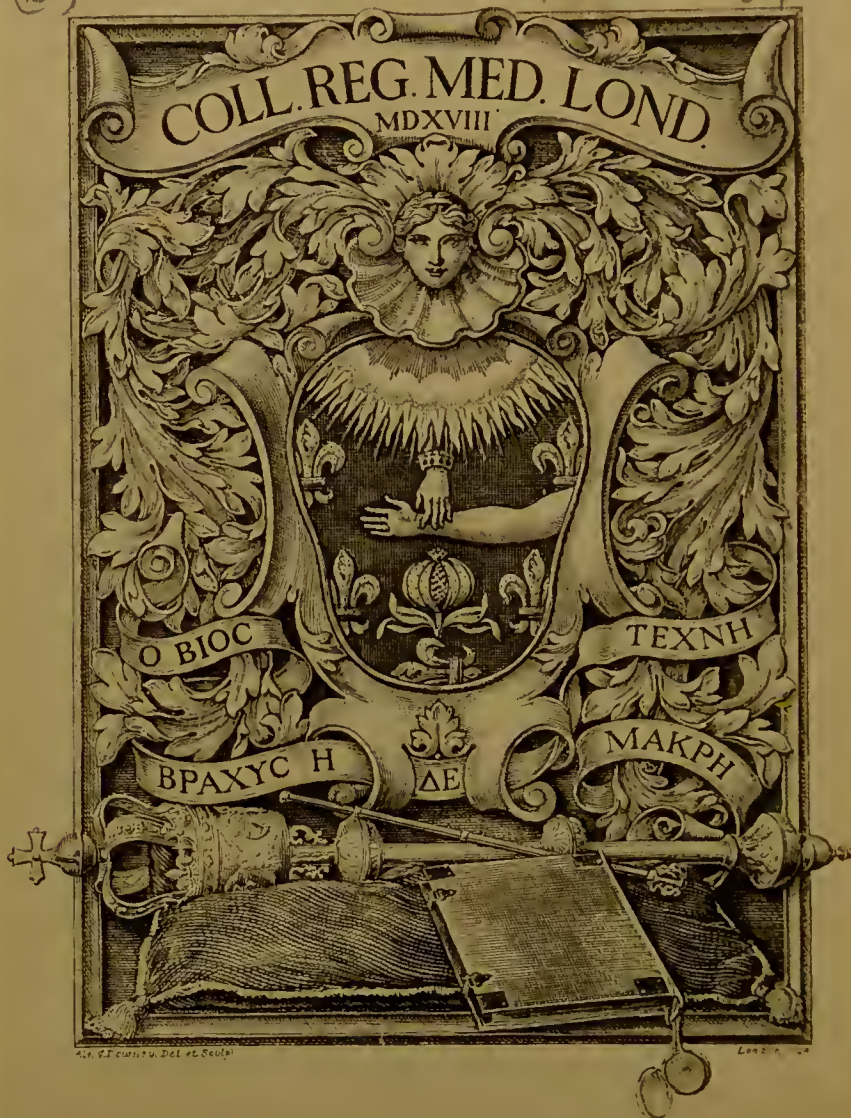




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E L E M E N T S

O F T H E

T H E O R Y o f C H Y M I S T R Y .





# E L E M E N T S

O F T H E

Theory and Practice

O F

# C H Y M I S T R Y

T R A N S L A T E D

*From the French of* M. MACQUER.

Member of the Royal Academy of Sciences, and Professor of Medicine in the University of Paris.

I N T W O V O L U M E S .

V O L . I .

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T H E F O U R T H E D I T I O N .

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L O N D O N ,

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TO THE  
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My LORD,

**T**HIS Translation of M. MACQUER'S celebrated ELEMENTS of CHYMISTRY was undertaken with the sole View of rendering some small Service to my Country; as I hoped it might contribute both to recommend and to facilitate the Study of a SCIENCE, which, though more entertaining, instructive, and extensively useful than any other, hath of late been too much neglected in this Island.

## DEDICATION.

I think myself very happy in seeing this Design approved of, and its Success in a manner assured, by the Honour which YOUR LORDSHIP hath been pleased to do me, in condescending to take it under your Protection.

I am, with the utmost Respect,

MY LORD,

YOUR LORDSHIP'S

most Obedient

and most Humble Servant

London,  
March 25, 1798.

ANDREW REID.



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THE  
AUTHOR'S  
PREFACE.

**A**N hundred and fifty years are scarce elapsed since the clouds of prejudice, which had long overspread the world, began to clear up, and men were convinced, by cultivating the Sciences and attending to Nature, that no fanciful hypotheses would ever lead them to the true causes of those various phenomena that incessantly and every where meet the observer's eye; but that the narrow limits of the human understanding confine the course of our researches to one single path; namely, that of Experiment, or the Use of our Senses. Yet, in this short period, Natural Philosophy hath risen to a high pitch of improvement, and may with truth be said to have made much greater advances towards perfection, since the experimental method was introduced, than in the many ages before.

This is true with regard to every branch of Natural Philosophy; but more particularly with regard to Chymistry. Though this Science cannot be said to have ever existed without experiments, yet it laboured under the same disadvantages with the rest; because those who studied it made all their experiments with a view to confirm their own Hypotheses, and in consequence of principles which had no foundation whatever, but in their wild imaginations.

Hence arose that enormous heap, that incongruous jumble of facts, which some time ago constituted all the knowledge of Chymists. Most of them, and especially those who assumed the pompous title of Alchymists, were persuaded that all the Metals were no other than Nature's rude unfinished essays towards making Gold; which, by means of due coction in the bowels of the earth, advanced gradually towards maturity, till at last they were perfectly converted into that beautiful and precious Metal.

On this principle, which, if not demonstrably false, is at least utterly destitute of proof, and unsupported by a single observation, they attempted to finish what Nature had begun, by procuring to the imperfect Metals this much desired coction. To attain it they made an infinite number of experiments and trials; which all conspired to detect the falsity of their system, and to satisfy men of sense, that the methods they employed were very far from answering the purpose.

However, as facts always promote the knowledge of Nature, it happened that those experiments, though quite useless with regard to the end for which they were originally made, proved the occasion of several curious discoveries.

These lucky consequences of their mistaken labours raised the courage of the Chymists, or rather Alchymists, who looked upon every such instance of success as a new step towards the Grand Work; and greatly increased the fond opinion they entertained of themselves, and of their Art, which on that account they set up very high above all other Sciences. Nay, they carried this notion of superiority so far, as to hold the rest of mankind unworthy, or incapable, of rising to such sublime knowledge. In consequence thereof Chymistry became an occult and mysterious Science; its ex-  
pressions

pressions were all tropes and figures, its phrases metaphorical, and its axioms so many enigmas: in short, an obscure unintelligible jargon is the justest character of the Alchymistic language.

Thus, by endeavouring to conceal their secrets, those gentlemen rendered their art useless to mankind, and brought it into deserved contempt. But at length the genius of true Philosophy prevailed in Chymistry, as well as in the other sciences. Some great men arose, who had generosity enough to think their knowledge no otherways valuable than as it proved of service to Society. They did their utmost to introduce both the knowledge and the practice of many important secrets, till then of no use; they drew aside the veil which hid the charms of Chymistry; and that Science emerging from the profound obscurity in which it had for many ages lain concealed, gained the admiration of the world as soon as it appeared in open day. Several societies of ingenious men were formed in the most learned countries of Europe, who vied with one another in their labours to execute the noble scheme, and assisted each other by mutually communicating their discoveries. Chymistry made the most rapid progress, enriching and perfecting the Arts derived from, or depending on it. In a word, it put on a new face, and became truly worthy of the title of Science; founding its principles and its processes on solid experiments, and on just consequences deduced from them.

Since that time the Art is become so extensive, by the numerous discoveries which Chymists have already made, and are daily making, that large volumes are required to contain a complete Treatise on the subject. In short, Chymistry may now, in some degree, be compared to Geometry; each of these Sciences takes in a most ample field of enquiry,



quiry, which every day enlarges very considerably; from each are derived several Arts, not only useful but even necessary to Society; each hath its Axioms and its undeniable principles, either demonstrated from internal evidence, or founded on constant experience; so that the one, as well as the other, may be reduced to certain fundamental truths, on which all the rest are built. These fundamental truths connected together, and laid down with order and precision, form what we call the Elements of a Science. It is well known that there are many such works relating to Geometry, but it is not so with regard to Chymistry; there being very few books which treat of this Science in an Elementary manner.

Yet it must be owned that performances of this kind are exceedingly useful. Many who have a relish for the Sciences, but have not leisure to read elaborate Works which treat of them minutely, are glad to meet with a book from which, without sacrificing too much of their time, or neglecting their ordinary business, they may obtain a taste or just notion of a Science that is not their principal study. Those who incline to go further, and learn more, may, by reading an Elementary tract, be enabled to understand Authors who, as they commonly write only for proficients in the Art, are obscure and hardly intelligible to mere beginners. Nay, I presume to say that an Elementary Treatise of Chymistry may prove a very useful book, even to those who have made some progress in the Science: for as it contains only the fundamental propositions, and indeed is an abstract of the whole Art, it may help them to recollect the most important parts of what they have read in many different works, and fix in their memories the most essential truths, which might else be either confounded with others, or entirely forgot. And these are the motives which determined

mined me to compose the Work which I now offer to the Publick.

The general plan on which I proceed is to suppose my Reader an absolute Novice in Chymistry; to lead him from the most simple truths, and such as imply the lowest degree of knowledge, to such as are more complex, and require a greater acquaintance with Nature. This order, which I have laid down for my rule, hath obliged me to begin with examining the most simple substances that we know; and which we consider as the elements whereof others are composed; as, by knowing the properties of these elementary parts, we are naturally led to those of their several combinations; and on the other hand, in order to know the properties of compound bodies, it is necessary we should be first acquainted with the properties of their principles. The same reason induced me, when enquiring into the properties of one substance, to take no notice of those which relate to any other substance not treated of before. For example: as I treat of Acids before Metals, I say nothing under the head of those Acids concerning their power of dissolving Metals: that I defer till I come to the subject of Metals: and thus I avoid speaking prematurely of a substance with which I suppose my Reader wholly unacquainted. And this method I was so much the more easily induced to follow, that I know of no Chymical book written on the same Plan.

After discoursing of Elements in general, I treat next of such substances as are immediately composed of them, and are, next to them, the most simple: such are all saline substances. This head comprehends mineral Acids, fixed Alkalis, and their several combinations: the volatile sulphureous spirit, sulphur, phosphorus, and the Neutral salts which have an earth or fixed Alkali for their basis: those  
 7 which



which have for their basis either a volatile Alkali, or some metallic substance, are referred, according to my general Plan, to the heads under which I treat of those substances.

Metallic substances are scarcely more compounded than the saline; which induces me to consider them next. I begin with those which are the most simple, or at least seem to be so; because their principles, being very strongly connected together, are separated with the greatest difficulty: such are the Metals properly so called; namely Gold, Silver, Copper, Iron, Tin, and Lead. After these come the Semi-metals in order; to wit, Regulus of Antimony, Zinc, Bismuth, and Regulus of Arsenic. Mercury being a doubtful substance, which some Chymists rank with the Metals, and others with the Semi-metals, because it actually possesses certain properties in common with each, I have treated of it in a separate Chapter, which stands between the Metals and Semi-metals.

I next proceed to examine the several sorts of Oils, whether Vegetable, which are divided into fat, essential, and empyreumatic; or Animal, and Mineral Oils.

By examining these substances we obtain ideas of all the principles which enter into the composition of Vegetable and Animal bodies; that is, of those substances that are capable of fermentation: this enables me to treat of fermentation in general; of its three different degrees or kinds, the spirituous, acetous, and putrid; and of the products of those fermentations, ardent spirits, acids analogous to those of vegetables and animals, and volatile alkalis.

The order in which I treat of all those substances being different from that in which they are obtained from compound bodies, I give, in a distinct chapter, a general Idea of Chymical Decomposition, with a  
view

view to shew the order in which they are separated from the several bodies in the composition whereof they are found. This brings them a second time under review, and gives me an opportunity of distinguishing those which exist naturally in compound bodies, from those which are only the result of a new combination of some of their principles produced by the fire.

The succeeding Chapter explains the late Mr. Geoffroy's Table of Affinities; which I take to be of great use at the end of an Elementary Tract like this, as it collects into one point of view the most essential and fundamental doctrines which are dispersed through the work.

I conclude with an account of the Construction of such Vessels and Furnaces as are usually employed in Chymistry.

In this Part I say nothing of any manual operations, or the several ways of performing Chymical processes; reserving these particulars for my Treatise of Practical Chymistry, to which this must be considered as an Introduction.



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# E L E M E N T S

O F T H E

## T H E O R Y O F C H Y M I S T R Y.

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### C H A P. I.

*Of the PRINCIPLES of Bodies.*

**T**H E Object and chief End of Chymistry is to separate the different substances that enter into the composition of bodies; to examine each of them apart; to discover their properties and relations; to decompose those very substances, if possible; to compare them together, and combine them with others; to reunite them again into one body, so as to reproduce the original compound with all its properties; or even to produce new compounds that never existed among the works of nature, from mixtures of other matters differently combined.

But this Analysis, or Decomposition, of Bodies is finite; for we are unable to carry it beyond a certain limit. In whatever way we attempt to go



further, we are always stopped by substances in which we can produce no change, which are incapable of being resolved into others, and which stand as so many firm barriers obstructing our progress.

To these substances we may, in my opinion, give the title of Principles or Elements: at least they are really such with regard to us. Of this kind the principal are Earth, Water, Air, and Fire. For though there be reason to think that these are not the first component parts, or the most simple elements, of matter; yet, as we know by experience, that our senses cannot possibly discover the principles of which they are composed, it seems more reasonable to fix upon them, and consider them as simple homogeneous bodies, and the principles of the rest, than to tire our minds with vain conjectures about the parts or elements of which they may consist; seeing there is no criterion by which we can know whether we have hit upon the truth, or whether the notions we have formed are mere fancies. We shall therefore consider these four substances as the principles or elements of all the various compounds which nature presents to our enquiries: because of all those we know they are in fact the most simple; and because all our decompositions, all our experiments on other bodies, plainly prove that they are at last resolvable into these primary parts.

These principles do not enter in the same proportion into all bodies: there are even some mixts in the composition of which this or that particular principle is not to be found. Thus Air and Water seem to be wholly excluded from the texture of Metals: at least all the experiments hitherto made on them seem to establish this opinion.

The substances composed immediately of these *First Elements* we shall call *Secondary Principles*; because

because in reality their several combinations with each other, the interchangeable coalitions that take place between them, constitute the different natures of all other bodies; which, as they result from the union both of primary and secondary principles, are properly entitled to the name of Compounds or Mixts.

Before we enter upon the examination of Compound Substances, it is necessary to consider the most Simple ones, or our four First Principles, with some attention, in order to discover their chief properties.

### §. I. *Of AIR.*

AIR is that Fluid which we constantly breathe, and which encompasses the whole surface of the terrestrial globe. Being heavy, like all other bodies, it penetrates into all places that are not either absolutely inaccessible, or filled with some other body heavier than itself. Its principal property is to be susceptible of condensation and rarefaction; so that the very same quantity of Air may occupy a much greater, or a much smaller space, according to the different state it is in. Heat and cold, or, if you will, the presence and the absence of the particles of Fire, are the most usual causes, and indeed the measures, of its condensation and rarefaction: for if a certain quantity of Air be heated, its bulk enlarges in proportion to the degree of heat applied to it; the consequence whereof is, that the same space now contains fewer particles of Air than it did before. Cold again produces just the contrary effect.

On this property which Air has, of being condensed and dilated by heat, its elasticity chiefly depends. For if Air were forced by condensation into a less compass than it took up before, and then exposed to a very considerable degree of cold, it would remain quite inactive, without exert-



ing such an effort as it usually makes against the compressing body. On the other hand, the elasticity of heated Air arises only from hence, that being rarefied by the action of fire, it requires much more room than it occupied before.

Air enters into the composition of many substances; especially vegetable and animal bodies: for by analysing most of them such a considerable quantity thereof is extricated, that some naturalists have suspected it to be altogether destitute of elasticity when thus combined with the other principles in the composition of bodies. According to them the efficacy of the elastic power of the Air is so prodigious, and its force when compressed so excessive, that it is not possible the other component parts of bodies should be able to confine so much of it, in that state of compression which it must needs undergo, if retaining its elasticity it were pent up among them.

However that be, this elastic property of the Air produces the most singular and important phenomena, observable in the resolution and composition of bodies.

## §. II. Of WATER.

WATER is a thing so well known, that it is almost needless to attempt giving a general idea of it here. Every one knows that it is a transparent, insipid substance, and usually fluid. I say it is usually so; for being exposed to a certain degree of cold it becomes solid: solidity therefore seems to be its most natural state.

Water exposed to the fire grows hot; but only to a limited degree, beyond which its heat never rises, be the force of fire applied to it ever so violent: it is known to have acquired this degree of heat by its boiling up with great tumult. Water cannot be made hotter, because it is volatile, and incapable of enduring the heat, without being evaporated and entirely dissipated.

If such a violent and sudden heat be applied to Water, as will not allow it time to exhale gently in vapours, as when, for instance, a small quantity thereof is thrown upon a metal in fusion, it is dissipated at once with vast impetuosity, producing a most terrible and dangerous explosion. This surprising effect may be deduced from the instantaneous dilatation of the parts of the Water itself, or rather of the Air contained in it. Moreover, Water enters into the texture of many bodies, both compounds and secondary principles; but, like Air, it seems to be excluded from the composition of all metals and most minerals. For although an immense quantity of Water exists in the bowels of the Earth, moistening all its contents, it does not therefore follow that it is one of the principles of minerals. It is only interposed between their parts; for they may be entirely robbed of it, without any sort of decomposition: indeed it is not capable of an intimate connection with them.

### §. III. *Of EARTH.*

WE observed that the two principles above treated of are volatile; that is, the action of Fire separates them from the bodies they help to compose, carrying them quite off, and dissipating them. That of which we are now to speak, namely Earth, is fixed, and, when it is absolutely pure, resists the utmost force of Fire. So that, whatever remains of a body, after it hath been exposed to the power of the fiercest Fire, must be considered as containing nearly all its earthy principle, and consisting chiefly thereof. I qualify my expression thus for two reasons: the first is, because it often happens, that this remainder does not actually contain all the Earth which existed originally in the mixt body decomposed by Fire; since it will afterwards appear that Earth, though in its own nature fixed, may be ren-

dered volatile by being intimately united with other substances which are so; and that, in fact, it is common enough for part of the Earth of a body to be thus volatilized by its other principles: the second is, that what remains after the calcination of a body is not generally its Earth in perfect purity, but combined with some of its other principles, which, though volatile in their own natures, have been fixed by the union contracted between it and them. We shall, in the sequel, produce some examples to illustrate this theory.

Earth therefore, properly so called, is a fixed principle, which is permanent in the Fire. There is reason to think it very difficult, if not impossible, to obtain the terrene principle wholly free from every other substance: for after our utmost endeavours to purify them, the Earths we obtain from different compounds are found to have different properties, according to the different bodies from which they are procured; or else, if those Earths be pure, we must allow them to be essentially different, seeing they have different properties.

Earth, in general, with regard to its properties, may be distributed into *fusible*, and *unfusible*; that is, into Earth that is capable of melting or becoming fluid in the Fire, and Earth that constantly remains in a solid form, never melting in the strongest degree of heat to which we can expose it.

The former is also called *vitriifiable*, and the second *unvitriifiable* Earth; because, when Earth is melted by the force of fire, it becomes what we call *glass*, which is nothing but the parts of Earth brought into nearer contact, and more closely united by the means of fusion. Perhaps the Earth, which we look upon as incapable of vitrification, might be fused if we could apply to it a sufficient degree of heat. It is at least certain that some Earths, or stones, which separately resist the force of Fire so  
that



that they cannot be melted, become fusible when mixed together. Experience convinced Mr. du Hamel that lime-stone and slate are of this kind. It is however undoubtedly true that one Earth differs from another in its degree of fusibility: and this gives ground to believe, that there may be a species of Earth absolutely unvitriifiable in its nature, which, being mixed in different proportions with fusible Earths, renders them difficult to melt.

Whatever may be in this, as there are Earths which we are absolutely unable to vitrify, that is a sufficient reason for our division of them. Unvitriifiable Earths seem to be porous, for they imbibe Water; whence they have also got the name of *Absorbent Earths*.

#### §. IV. Of FIRE.

THE Matter of the Sun, or of Light, the Phlogiston, Fire, the Sulphureous Principle, the Inflammable Matter, are all of them names by which the Element of Fire is usually denoted. But it should seem, that an accurate distinction hath not yet been made between the different states in which it exists; that is, between the phenomena of Fire actually existing as a principle in the composition of bodies, and those which it exhibits when existing separately and in its natural state: nor have proper distinct appellations been assigned to it in those different circumstances. In the latter state we may properly give it the names of Fire, Matter of the Sun, of Light, and of Heat; and may consider it as a substance composed of infinitely small particles, continually agitated by a most rapid motion, and of consequence, essentially fluid.

This substance, of which the sun may be called the general reservoir, seems to flow incessantly from that source, diffusing itself over the world, and through all the bodies we know; but not as a prin-

ciple, or essential part of them, since they may be deprived thereof, at least in a great measure, without suffering any decomposition. The greatest change produced on them, by its presence or its absence, is the rendering them fluid or solid: so that all other bodies may be deemed naturally solid; Fire alone essentially fluid, and the principle of fluidity in others. This being presupposed, Air itself might become solid, if it could be entirely deprived of the Fire it contains; as bodies of most difficult fusion become fluid, when penetrated by a sufficient quantity of the particles of Fire.

One of the chief properties of this pure Fire is to penetrate easily into all bodies, and to diffuse itself among them with a sort of uniformity and equality: for if a heated body be contiguous to a cold one, the former communicates to the latter all its excess of heat, cooling in exact proportion as the other warms, till both come to have the very same degree of heat. Heat, however, is naturally communicable soonest to the upper parts of a body; and consequently, when a body cools, the under parts become soonest cold. It hath been observed, for instance, that the lower extremity of a heated body, freely suspended in the air, grows cold sooner than the upper; and that when a bar of iron is red-hot at one end, and cold at the other, the cold end is much sooner heated by placing the bar so that the hot end may be undermost, than when that end is turned uppermost. The levity of the matter of Fire, and the vicinity of the Earth, may possibly be the causes of this phenomenon.

Another property of Fire is to dilate all bodies into which it penetrates. This hath already been shewn with regard to Air and Water; and it produces the same effect on Earth.

Fire is the most powerful agent we can employ to decompose bodies; and the greatest degree of



heat producible by man, is that excited by the rays of the sun collected in the focus of a large burning-glass.

§. V. *Of the PHLOGISTON.*

FROM what hath been said concerning the nature of Fire, it is evidently impossible for us to fix and confine it in any body. Yet the phenomena attending the combustion of inflammable bodies shew, that they really contain the matter of Fire as a constituent principle. By what mechanism then is this fluid, which is so subtle, so active, so difficult to confine, so capable of penetrating into every other substance in nature; how comes it, I say, to be so fixed as to make a component part of the most solid bodies? It is no easy matter to give a satisfactory answer to this question. But, without pretending to guess the cause of the phenomenon, let us rest contented with the certainty of the fact, the knowledge of which will undoubtedly procure us considerable advantages. Let us therefore examine the properties of Fire thus fixed and become a principle of bodies. To this substance, in order to distinguish it from pure and unfixed Fire, the Chymists have assigned the peculiar title of the *Phlogiston*, which is indeed no other than a Greek word for the Inflammable Matter; by which latter name, as well as by that of the Sulphureous Principle, it is also sometimes called. It differs from elementary Fire in the following particulars. 1. When united to a body, it communicates to it neither heat nor light. 2. It produces no change in its state, whether of solidity or fluidity; so that a solid body does not become fluid by the accession of the Phlogiston, and *vice versa*; the solid bodies to which it is joined being only rendered thereby more apt to be fused by the force of the culinary Fire. 3. We can convey it from the body, with which it is joined, into another body,

body, so that it shall enter into the composition thereof, and remain fixed in it.

On this occasion both these bodies, that which is deprived of the Phlogiston and that which receives it, undergo very considerable alterations; and it is this last circumstance, in particular, that obliges us to distinguish the Phlogiston from pure Fire, and to consider it as the element of Fire combined with some other substance, which serves it as a basis for constituting a kind of secondary principle. For if there were no difference between them, we should be able to introduce and fix pure Fire itself, wherever we can introduce and fix the Phlogiston: yet this is what we can by no means do, as will appear from experiments to be afterwards produced.

Hitherto Chymists have never been able to obtain the Phlogiston quite pure, and free from every other substance: for there are but two ways of separating it from a body of which it makes a part; to wit, either by applying some other body with which it may unite the moment it quits the former; or else by calcining and burning the compound from which you desire to sever it. In the former case it is evident that we do not get the Phlogiston by itself, because it only passes from one combination into another; and in the latter, it is entirely dissipated in the decomposition, so that no part of it can possibly be secured.

The inflammability of a body is an infallible sign that it contains a Phlogiston; but from a body's not being inflammable, it cannot be inferred that it contains none: for experiments have demonstrated that certain metals abound with it, which yet are by no means inflammable.

We have now delivered what is most necessary to be known concerning the principles of bodies in general. They have many other qualities besides those above-mentioned; but we cannot properly  
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take notice of them here, because they presuppose an acquaintance with some other things relating to bodies, of which we have hitherto said nothing; intending to treat of them in the sequel as occasion shall offer. We shall only observe in this place, that when animal and vegetable matters are burnt, in such a manner as to hinder them from flaming, some part of the Phlogiston contained in them unites intimately with their most fixed earthy parts, and with them forms a compound, that can be consumed only by making it red-hot in the open air, where it sparkles and wastes away, without emitting any flame. This compound is called a *Coal*. We shall enquire into the properties of this Coal under the head of Oils: at present it suffices that we know in general what it is, and that it readily communicates to other bodies the Phlogiston it contains.

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## C H A P. II.

### *A general View of the Relations or Affinities between Bodies.*

**B**EFORE we can reduce compound Bodies to the first principles above pointed out, we obtain, by analysing them, certain substances which are indeed more simple than the bodies they helped to compose, yet are themselves composed of our primary principles. They are therefore at one and the same time both principles and compounds; for which reason we shall, as was before said, call them by the name of Secondary Principles. Saline and oily matters chiefly constitute this class. But before we enter upon an examination of their properties, it is fit we lay before the Reader a general view of what Chymists understand by the Relations or Affinities



Affinities of Bodies; because it is necessary to know these, in order to make a distinct conception of the different combinations we are to treat of.

All the experiments hitherto made concur with daily observation to prove that different bodies, whether principles or compounds, have such a mutual Conformity, Relation, Affinity, or Attraction, if you will call it so, as disposes some of them to join and unite together, while they are incapable of contracting any union with others. This effect, whatever be its cause, will enable us to account for, and connect together, all the phenomena that Chymistry produces. The nature of this universal affection of matter is distinctly laid down in the following propositions.

First, If one substance hath any Affinity or conformity with another, the two will unite together, and form one compound.

Secondly, It may be laid down as a general rule, that all similar substances have an Affinity with each other, and are consequently disposed to unite; as water with water, earth with earth, &c.

Thirdly, Substances that unite together lose some of their separate properties; and the compounds resulting from their union partake of the properties of those substances which serve as their principles.

Fourthly, The simpler any substances are, the more perceptible and considerable are their Affinities: whence it follows, that the less bodies are compounded, the more difficult it is to analyse them; that is, to separate from each other the principles of which they consist.

Fifthly, If a body consist of two substances, and to this compound be presented a third substance that has no Affinity at all with one of the two primary substances aforesaid, but has a greater Affinity with the other than those two substances have with each other, there will ensue a decomposition, and a  
new

new union; that is, the third substance will separate the two compounding substances from each other, coalesce with that which has an Affinity with it, form therewith a new combination, and disengage the other, which will then be left at liberty, and such as it was before it had contracted any union.

Sixthly, It happens sometimes that when a third substance is presented to a body consisting of two substances, no decomposition follows; but the two compounding substances, without quitting each other, unite with the substance presented to them, and form a combination of three principles: and this comes to pass when that third substance has an equal, or nearly equal, Affinity with each of the compounding substances. The same thing may also happen even when the third substance hath no Affinity but with one of the compounding substances only. To produce such an effect, it is sufficient that one of the two compounding substances have to the third body a Relation equal, or nearly equal, to that which it has to the other compounding substance with which it is already combined. Thence it follows, that two substances, which, when apart from all others, are incapable of contracting any union, may be rendered capable of incorporating together in some measure, and becoming parts of the same compound, by combining with a third substance with which each of them has an equal Affinity.

Seventhly, A body, which of itself cannot decompose a compound consisting of two substances, because, as we just now said, they have a greater Affinity with each other than it has with either of them, becomes nevertheless capable of separating the two by uniting with one of them, when it is itself combined with another body, having a degree of Affinity with that one, sufficient to compensate its own want thereof. In that case there are two Affinities, and thence ensues a double decomposition and a double combination. These



These fundamental truths, from which we shall deduce an explanation of all the phenomena in Chymistry, will be confirmed and illustrated by applying them, as we shall do, to the several cases, of which our design in this Treatise obliges us to give a circumstantial account.

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### C H A P. III.

#### *Of Saline Substances in general.*

**I**F a particle of water be intimately united with a particle of earth, the result will be a new compound, which, according to our third proposition of Affinities, will partake of the properties of earth and of water; and this combination principally forms what is called a *Saline Substance*. Consequently every saline Substance must have an affinity with earth and with water, and be capable of uniting with both or either of them, whether they be separate or mixed together: and accordingly this property characterises all Salts, or Saline Substances, in general.

Water being volatile and Earth fixed, Salts in general are less volatile than the former, and less fixed than the latter; that is, fire, which cannot volatilize and carry off pure earth, is capable of rarefying and volatilizing a Saline Substance; but then this requires a greater degree of heat than is necessary for producing the same effects on pure water.

There are several sorts of Salts, differing from one another, in respect either of the quantity, or the quality of the earth in their composition; or lastly, they differ on account of some additional principles, which not being combined with them in sufficient quantity to hinder their Saline properties

ties from appearing, permit them to retain the name of Salts, though they render them very different from the simplest Saline Substances.

It is easy to infer, from what has been said of Salts in general, that some of them must be more, some less, fixed or volatile than others, and some more, some less, disposed to unite with water, with earth, or with particular sorts of earth, according to the nature or the proportion of their principles.

Before we proceed further, it is proper just to mention the principal reasons, which induce us to think that every Saline Substance is actually a combination of earth and water, as we supposed at our entering on this subject. The first is, the conformity Salts have with earth and water, or the properties they possess in common with both. Of these properties we shall treat fully, as occasion offers to consider them, in examining the several sorts of Salts. The second is, that all Salts may be actually resolved into earth and water by sundry processes; particularly by repeated dissolution in water, evaporation, desiccation, and calcination. Indeed the Chymists have not yet been able to procure a Saline Substance, by combining earth and water together. This favours a suspicion, that, besides these two, there is some other principle in the composition of Salts, which escapes our researches, because we cannot preserve it when we decompose them: but it is sufficient to our purpose, that water and earth are demonstrably amongst the real principles of Saline Substances, and that no experiment hath ever shewn us any other.

### §. I. Of Acids.

OF all Saline Substances, the simplest is that called an *Acid*, on account of its taste; which is like that of verjuice, sorrel, vinegar, and other sour things, which for the same reason are also called Acids. By this peculiar

peculiar taste are Acids chiefly known. They have moreover the property of turning all the blue and violet colours of vegetables red, which distinguishes them from all other salts.

The form, under which Acids most commonly appear, is that of a transparent liquor; though solidity is rather their natural state. This is owing to their affinity with water; which is so great that, when they contain but just as much of it as is necessary to constitute them Salts, and consequently have a solid form, they rapidly unite therewith the moment they come into contact with it: and as the air is always loaded with moisture and aqueous vapours, its contact alone is sufficient to liquify them; because they unite with its humidity, imbibe it greedily, and by that means become fluid. We therefore say, they attract the moisture of the air. This change of a salt from a solid to a fluid state, by the sole contact of the air, is also called *Deliquium*; so that when a salt changes in this manner from a solid into a fluid form, it is said to run *per deliquium*. Acids being the simplest species of Saline bodies, their affinities with different substances are stronger than those of any other sort of salt with the same substances; which is agreeable to our fourth proposition concerning Affinities.

Acids in general have a great affinity with earths: that with which they most readily unite is the unvitriifiable earth to which we gave the name of absorbent earth. They seem not to act at all upon vitriifiable earths, such as sand; nor yet upon some other kinds of earths, at least while they are in their natural state. Yet the nature of these earths may be in some measure changed, by making them red hot in the fire, and then quenching them suddenly in cold water: for by repeating this often they are brought nearer to the nature of absorbent earths, and rendered capable of uniting with Acids.

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When an acid liquor is mixed with an absorbent earth, for instance with chalk, these two substances instantly rush into union, with so much impetuosity, especially if the acid liquor be as much dephlegmated, or contain as little water, as may be, that a great ebullition is immediately produced, attended with considerable hissing, heat, and vapours, which rise the very instant of their conjunction.

From the combination of an Acid with an absorbent earth there arises a new compound, which some Chymists have called *Sal Salsum*; because the Acid by uniting with the earth loses its sour taste, and acquires another not unlike that of the common sea-salt used in our kitchens; yet varying according to the different sorts of Acids and earths combined together. The Acid at the same time loses its property of turning vegetable blues and violet colours red.

If we enquire what is become of its propensity to unite with water, we shall find that the earth, which of itself is not soluble in water, hath by its union with the Acid acquired a facility of dissolving therein; so that our *Sal Salsum* is soluble in water. But, on the other hand, the Acid hath, by its union with the earth, lost part of the affinity it had with water; so that if a *Sal Salsum* be dried and freed of all superfluous humidity, it will remain in that dry solid form, instead of attracting the moisture of the air, and running *per deliquium*, as the Acid would do if it were pure and unmixed with earth. However, this general rule admits of some exceptions; and we shall have occasion in another place to take notice of certain Combinations of Acids with earths, which still continue to attract the moisture of the air, though not so strongly as a pure Acid.

ACIDS have likewise a great affinity with the Phlogiston. When we come to treat of each Acid in particular, we shall examine the combinations of

each with the Phlogiston: they differ so widely from one another, and many of them are so little known, that we cannot at present give any general idea of them.

## §. II. *Of* ALKALIS.

ALKALIS are Saline combinations in which there is a greater proportion of earth than in Acids. The principal arguments that may be adduced to prove this fact are these: First; if they be treated in the manner proposed above for analyzing Saline Substances, we obtain from them a much greater quantity of earth than we do from Acids. Secondly; by combining certain Acids with certain earths we can produce Alkalis; or at least such saline compounds as greatly resemble them. Our third and last argument is drawn from the properties of those Alkalis which, when pure and unadulterated with any other principle, have less affinity with water than Acids have, and are also more fixed, resisting the utmost force of fire. On this account it is that they have obtained the title of *Fixed*, as well as to distinguish them from another species of Alkali, to be considered hereafter, which is impure and volatile.

Though fixed Alkalis, when dry, sustain the utmost violence of fire without flying off in vapours, it is remarkable that, being boiled with water in an open vessel, considerable quantities of them rise with the steam: an effect which must be attributed to the great affinity between these two substances, by means whereof water communicates some part of its volatility to the fixed salt.

Alkalis freed of their superfluous humidity by calcination attract the moisture of the air, but not so strongly as Acids: so that it is easier to procure and preserve them in a solid form.

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They flow in the fire, and are then capable of uniting with vitrifiable earths, and of forming therewith true glafs, which, however, will partake of their properties, if they be used in fufficient quantity.

As they melt more readily than vitrifiable earth, they facilitate its fufion; fo that a weaker fire will reduce it to glafs, when a fixed Alkali is joined with it, than will melt it without that addition.

Alkalis are known by their tafte, which is acrid and fiery; and by the properties they poffefs of turning certain vegetable blues and violet colours green; particularly fyrup of violets.

Their affinity with Acids is greater than that of abforbent earths; and hence it comes to pafs that if an Alkali be prefented to a combination of an Acid with an abforbent earth, the earth will be feparated from the Acid by the Alkali, and a new union between the Acid and the Alkali will take place. This is both an inftance and a proof of our fifth propofition concerning Affinities.

If a pure Alkali be prefented to a pure Acid, they rufh together with violence, and produce the fame phenomena as were obferved in the union of an abforbent earth with an Acid; but in a greater and more remarkable degree.

Fixed Alkalis may in general be divided into two forts: one of thefe hath all the above recited properties; but the other poffeffes fome that are peculiar to itfelf. We fhall confider this latter fort more particularly under the head of Sea-Salt.

### §. III. Of NEUTRAL SALTS.

THE Acid and the Alkali thus uniting mutually rob each other of their characteristic properties; fo that the compound resulting from their union produces no change in the blue colours of vegetables, and has a tafte which is neither four nor

acid, but saltish. A saline combination of this kind is for that reason named *Sal Salsum*, *Sal Medium*, or a *Neutral Salt*. Such combinations are called by the plain general name of *Salts*.

It must be observed that, in order to make these Salts perfectly Neutral, it is necessary that neither of the two saline principles of which they are compounded be predominant over the other; for in that case they will have the properties of the prevailing principle. The reason is this: neither of these saline substances can unite with the other but in a limited proportion, beyond which there can be no further coalition between them. The action by which this perfect union is accomplished is termed *Saturation*; and the instant when such proportions of the two saline substances are mixed together, that the one is incorporated with as much of the other as it can possibly take up, is called the *Point of Saturation*. All this is equally applicable to the combination of an Acid with an absorbent earth.

The combination is known to be perfect, that is, the Point of Saturation is known to be obtained, when after repeated affusions of an Acid in small quantities to an Alkali, or an absorbent earth, we find those phenomena cease, which in such cases constantly attend the conflict of union, as we said above, namely, ebullition, hissing, &c. and we may be assured the Saturation is complete when the new compound hath neither an acid nor an acid taste, nor in the least changes the blue colours of vegetables.

Neutral Salts have not so great an affinity with water as either Acids or Alkalis have; because they are more compounded: for we observed before, that the affinities of the most compounded bodies are generally weaker than those of the most simple. In consequence hereof few Neutral Salts, when dried, attract the moisture of the air; and those

that do, attract it more slowly, and in less quantity, than either Acids or Alkalis do.

All Neutral Salts are soluble in water; but more or less readily, and in a greater or smaller quantity, according to the nature of their component principles.

Water made boiling hot dissolves a greater quantity of those salts which do not attract the moisture of the air, than when it is cold; and indeed it must be boiling hot to take up as much of them as it is capable of dissolving: but as for those which run in the air, the difference, if there be any, is imperceptible.

Some Neutral Salts have the property of shooting into Crystals, and others have it not.

The nature of Crystallization is this: Water cannot dissolve, nor keep in solution, more than a determinate quantity of any particular Salt: when therefore such a quantity of water is evaporated from the solution of a Salt capable of crystallization, that the remainder contains just as much Salt as it can dissolve, then by continuing the evaporation the Salt gradually recovers its solid form, and concretes into several little transparent masses called Crystals. These crystals have regular figures, all differing from one another according to the species of Salt of which they are formed. Different methods of evaporating saline solutions have different effects on the figure and regularity of the crystals; and each particular sort of Salt requires a peculiar method of evaporation to make its crystals perfectly regular.

A solution of Salt designed for crystallization is usually evaporated by means of fire to a pellicle; that is, till the Salt begin to concrete; which is perceived by a kind of thin dark skin that gathers on the surface of the liquor, and is formed of the crystallized particles of Salt. When this pellicle appears the solution is suffered to cool, and the cry-



stals form therein faster or slower according to the sort of Salt in hand. If the evaporation be carried on briskly to perfect dryness, no crystals will be formed, and only an irregular mass of Salt will be obtained.

The reasons why no crystals appear when the evaporation is hastily performed, and carried on to dryness, are, first, that the particles of Salt, being always in motion while the solution is hot, have not time to exert their mutual affinities, and to unite together as crystallization requires: secondly, that a certain quantity of water enters into the very composition of crystals; which is therefore absolutely necessary to their formation, and in a greater or smaller proportion according to the nature of the Salt \*.

If these crystallized Salts be exposed to the fire, they first part with that moisture which is not necessary to a saline concretion, and which they retained only by means of their crystallization: afterwards they begin to flow, but with different degrees of fusibility.

It must be observed that certain Salts melt as soon as they are exposed to the fire; namely, those which retain a great deal of water in crystallizing. But this fluid which they so readily acquire must be carefully distinguished from actual fusion: for it is owing only to their superfluous humidity, which heat renders capable of dissolving and liquifying them; so that when it is evaporated the Salt ceases to be fluid, and requires a much greater degree of fire to bring it into real fusion.

The Neutral Salts that do not crystallize may, indeed, be dried by evaporating the water which

\* Those who have the curiosity to see a more particular account of the Crystallization of Neutral Salts, may read Mr. *Rouelle's* excellent Memoir on that Subject, among those of the Academy of Sciences for 1744.



keeps them fluid; but by becoming solid they acquire no regular form; they again attract the moisture of the air, and are thereby melted into a liquor. These may be called *Liquescent Salts*.

Most of the Neutral Salts, that consist of an Acid joined with a fixed Alkali, or with an absorbent earth, are themselves fixed, and resist the force of fire; yet several of them, if they be dissolved in water, and the solution boiled and evaporated, fly off along with the steams.

## C H A P. IV.

### *Of the several Sorts of Saline Substances.*

#### §. I. *Of the UNIVERSAL ACID.*

THE Universal Acid is so called, because it is in fact the Acid which is most universally diffused through all nature, in waters, in the atmosphere, and in the bowels of the earth. But it is seldom pure; being almost always combined with some other substance. That from which we obtain it with most ease and in the greatest quantity is Vitriol, a mineral which we shall consider afterwards: and this is the reason why it is called the *Vitriolic Acid*; the name by which it is best known.

When the Vitriolic Acid contains but little phlegm, yet enough to give it a fluid form, it is called *Oil of Vitriol*; on account of a certain unctuousity belonging to it. In truth this name is very improperly bestowed on it; for we shall afterwards see that, bating this unctuousness, it has none of the properties of oils. But this is not the only impropriety in names that we shall have occasion to censure.

If the Vitriolic Acid contain much water it is then called *Spirit of Vitriol*. When it does not contain enough to render it fluid, and so is in a solid form, it is named the *Icy Oil of Vitriol*.

When Oil of Vitriol highly concentrated is mixed with water, they rush into union with such impetuosity that, the moment they touch each other, there arises a hissing noise, like that of red-hot iron plunged in cold water, together with a very considerable degree of heat, proportioned to the degree to which the Acid was concentrated.

If instead of mixing this concentrated Acid with water, you only leave it exposed to the air for some time, it attracts the moisture thereof, and imbibes it most greedily. Both its bulk and its weight are increased by this accession; and if it be under an icy form, that is, if it be concentered, the phlegm thus acquired will soon resolve it into a fluid.

The addition of water renders the Vitriolic Acid, and indeed all other Acids, weaker in one sense; which is, that when they are very aqueous they leave on the tongue a much fainter taste of acidity, and are less active in the solution of some particular bodies: but that occasions no change in the strength of their affinities, but in some cases rather enables them to dissolve several substances, which, when well dephlegmated, they are not capable of attacking.

The Vitriolic Acid combined to the point of saturation with a particular absorbent earth, the nature of which is not yet well known, forms a Neutral Salt that crystallizes. This Salt is called *Alum*, and the figure of its crystals is that of an octahedron, or solid of eight sides. These octahedra are triangular pyramids, the angles of which are so cut off that four of the surfaces are hexagons, and the other four triangles.

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There are several sorts of Alum, which differ according to the earths combined with the Vitriolic Acid. Alum dissolves easily in water, and in crystallization retains a considerable quantity of it; which is the reason that being exposed to the fire it readily melts, swelling and puffing up as its superfluous moisture exhales. When that is quite evaporated, the remainder is called *Burnt Alum*, and is very difficult to fuse. The Acid of the Alum is partly dissipated by this calcination. Its taste is saltish, with a degree of roughness and astringency.

The Vitriolic Acid combined with certain earths forms a kind of Neutral Salt called *Selenites*, which crystallizes in different forms according to the nature of its earth. There are numberless springs of water infected with dissolved Selenites; but when this Salt is once crystallized, it is exceeding difficult to dissolve it in water a second time. For that purpose a very great quantity of water is necessary, and moreover it must boil; for as it cools most of the dissolved Selenites takes a solid form, and falls in a powder to the bottom of the vessel.

If an Alkali be presented to the Selenites, or to Alum, these Salts, according to the principles we have laid down, will be thereby decomposed; that is, the Acid will quit the earths, and join the Alkali, with which it hath a greater affinity. And from this conjunction of the Vitriolic Acid with a fixed Alkali there results another sort of Neutral Salt, which is called *Arcanum duplicatum*, *Sal de duobus*, and *Vitriolated Tartar*, because one of the fixed Alkalis most in use is called Salt of Tartar.

Vitriolated Tartar is almost as hard to dissolve in water as the Selenites. It shoots into eight-sided crystals, having the apices of the pyramids pretty obtuse. Its taste is saltish, inclining to bitter; and it decrepitates on burning coals. It requires a very great degree of fire to make it flow.

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The Vitriolic Acid is capable of uniting with the Phlogiston, or rather it has a greater affinity with it than with any other body: whence it follows that all compounds, of which it makes a part, may be decomposed by means of the Phlogiston.

From the conjunction of the Vitriolic Acid with the Phlogiston arises a compound called *Mineral Sulphur*, because it is found perfectly formed in the bowels of the earth. It is also called *Sulphur vivum*, or simply, *Sulphur*.

Sulphur is absolutely insoluble in water, and incapable of contracting any sort of union with it. It melts with a very moderate degree of heat, and sublimes in fine light downy tufts called *Flowers of Sulphur*. By being thus sublimed it suffers no decomposition, let the operation be repeated ever so often; so that Sublimed Sulphur, or Flower of Sulphur, hath exactly the same properties as Sulphur that has never been sublimed.

If Sulphur be exposed to a brisk heat in the open air, it takes fire, burns, and is wholly consumed. The desflagration of Sulphur is the only means we have of decomposing it, in order to obtain its Acid in purity. The Phlogiston is destroyed by the flame, and the Acid exhales in vapours: these vapours collected have all the properties of the Vitriolic Acid, and differ from it only as they still retain some portion of the Phlogiston; which, however, soon quits them of its own accord, if the free access of the common air be not precluded.

The portion of Phlogiston retained by the Acid of Sulphur is much more considerable when that mineral is burnt gradually and slowly: in that case the vapours which rise from it have such a penetrating odour, that they instantaneously suffocate any person who draws in a certain quantity of them with his breath. These vapours constitute what is called the *Volatile Spirit of Sulphur*. There is reason to think



think this portion of Phlogiston which the Acid retains is combined therewith in a manner different from that in which these two are united in the Sulphur itself; for, as has just been observed, nothing but actual burning is capable of separating the Vitriolic Acid and the Phlogiston, which by their union form Sulphur; whereas in the Volatile Spirit of Sulphur they separate spontaneously when exposed to the open air; that is, the Phlogiston flies off and leaves the Acid, which then becomes in every respect similar to the Vitriolic Acid.

That the Volatile Spirit of Sulphur is a compound, as we have asserted it to be, appears evidently from hence, that whenever the Vitriolic Acid touches any substance containing the Phlogiston, provided that Phlogiston be disengaged or opened to a certain degree, a Volatile Spirit of Sulphur is infallibly and immediately generated. This Spirit hath all the properties of Acids, but considerably weakened, and of course less perceptible. It unites with absorbent earths or fixed Alkalis; and with them forms Neutral Salts: but when combined therewith it may be separated from them by the Vitriolic Acid, and indeed by any of the mineral Acids, because its affinities are weaker. Sulphur hath the property of uniting with absorbent earths, but not near so intimately as with fixed Alkalis.

If equal parts of Sulphur and an Alkali be melted together, they incorporate with each other; and from their conjunction proceeds a compound of a most unpleasant smell, much like that of rotten eggs, and of a red colour nearly resembling that of an animal liver, which has occasioned it to bear the name of *Hepar Sulphuris*, or *Liver of Sulphur*.

In this composition the fixed Alkali communicates to the Sulphur the property of dissolving in water: and hence it comes that Liver of Sulphur may be made as well when the Alkali is dissolved  
by

by water into a fluid, as when it is fused by the action of fire.

Sulphur has less affinity than any Acid with the fixed Alkalis: and therefore Liver of Sulphur may be decomposed by any Acid whatever; which will unite with the fixed Alkali, form therewith a Neutral Salt, and separate the Sulphur.

If Liver of Sulphur be dissolved in water, and an Acid poured thereon, the liquor, which was transparent before, instantly turns to an opaque white; because the Sulphur, being forced to quit its union with the Alkali, loses at the same time the property of dissolving in water, and appears again in its own opaque form. The liquor thus made white by the Sulphur is called *Milk of Sulphur*.

If this liquor be suffered to stand still for some time, the particles of Sulphur, now most minutely divided, gradually approach each other, unite, and fall insensibly to the bottom of the vessel; and then the liquor recovers its transparency. The Sulphur thus deposited on the bottom of the vessel is called the *Magistery* or *Precipitate of Sulphur*. The names of *Magistery* and *Precipitate* are also given to all substances whatever that are separated from another by this method; which is the reason that we use the expression of precipitating one substance by another, to signify the separating one of them by means of the other.

## §. II. Of the NITROUS ACID.

It is not certainly known what constitutes the difference between the Nitrous Acid and the Vitriolic Acid, with regard to the constituent principles of each. The most probable opinion is, that the Nitrous Acid is no other than the Vitriolic Acid combined with a certain quantity of Phlogiston by the

the means of putrefaction. If it be so, the Phlogiston must be united with the Universal Acid in another manner than it is in sulphur, and in its volatile spirit: for the Nitrous Acid differs from them both in its properties. What gives ground for this opinion is, that the Nitrous Acid is never found but in earths and stones which have been impregnated with matters subject to putrefaction, and which therefore must contain the Phlogiston. For it is necessary just to observe here, though it be not yet proper to enter particularly into the subject, that all substances susceptible of putrefaction really contain the Phlogiston.

The Nitrous Acid combined with certain absorbent earths, such as chalk, marle, boles, forms Neutral Salts which do not crystallize; and which, after being dried, run in the air *per deliquium*.

All those Neutral Salts which consist of the Nitrous Acid joined to an earth, may be decomposed by a fixed Alkali, with which the Acid unites, and deserts the earth; and from this union of the Nitrous Acid with a fixed Alkali results a new Neutral Salt which is called *Nitre*, or *Salt-petre*. This latter name signifies the *Salt of Stone*; and in fact Nitre is extracted from the stones and plaister, in which it forms, by boiling them in water saturated with a fixed Alkali.

Nitre shoots in long crystals adhering sideways to each other: it has a saltish taste, which produces a sensation of cold on the tongue.

This Salt easily dissolves in water; which, when boiling hot, takes up still a greater quantity thereof.

It flows with a pretty moderate degree of heat, and continues fixed therein: but being urged by a brisk fire, and in the open air, it lets go some part of its Acid, and indeed flies off itself in part.

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The most remarkable property of Nitre, and that which characterizes it, is its Fulmination or Explosion; the nature of which is as follows:

When Nitre touches any substance containing a Phlogiston, and actually ignited, that is, actually on fire, it bursts out into a flame, burns, and is decomposed with much noise.

In this deflagration the Acid is dissipated, and totally separated from the Alkali, which now remains by itself.

Indeed the Acid, at least the greatest part of it, is by this means quite destroyed. The Alkali which is left when Nitre is decomposed by deflagration, is called in general *Fixed Nitre*, and, more particularly, Nitre fixed by such and such a substance as was used in the operation. But if Nitre be deflagrated with an inflammable substance containing the vitriolic Acid, as sulphur, for instance, the fixed Salt produced by the deflagration is not a pure Alkali, but retains a good deal of the vitriolic Acid, and, by combining therewith, hath now formed a neutral Salt.

Hitherto Chymists have been at a loss for the reason why Nitre flames, and is decomposed in manner above mentioned, when it comes in contact with a Phlogiston properly circumstanced. For my part, I conjecture it to be for the same reason that vitriolated tartar is also decomposed by the addition of a Phlogiston; viz. the Nitrous Acid, having a greater affinity with the Phlogiston than with the fixed Alkali, naturally quits the latter to join with the former, and so produces a kind of sulphur, differing probably from the common sulphur, formed by the vitriolic Acid, in that it is combustible to such a degree, as to take fire and be consumed in the very moment of its production; so that it is impossible to prevent its being thus destroyed, and consequently impossible to save it. In support of this opinion  
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let it be considered, that the concurrence of the Phlogiston is absolutely necessary to produce this deflagration, and that the matter of pure fire is altogether incapable of effecting it: for though Nitre be exposed to the most violent degree of fire, even that in the focus of the most powerful burning-glass, it will not flame; nor will that effect ever happen till the Nitre be brought into contact with a Phlogiston properly so called, that is, the matter of fire existing as a principle of some body; and it is moreover necessary that this Phlogiston be actually on fire, and agitated with the igneous motion, or else that the Nitre itself be red-hot, and so penetrated with fire as to kindle any inflammable matter that touches it.

This experiment, among others, helps to shew the distinction that ought to be made between pure elementary fire, and fire become a principle of bodies, to which we have given the name of Phlogiston.

Before we leave this subject, we shall observe that Nitre deflagrates only with such substances as contain the Phlogiston in its simplest and purest form; such as charcoal, sulphur, and the metalline substances; and that, though it will not deflagrate without the addition of some combustible matter, it is nevertheless the only known body that will burn, and make other combustibles burn with it, in close vessels, without the admission of fresh air.

The Nitrous Acid hath not so great an affinity with earths and Alkalis as the vitriolic Acid hath with the same substances; whence it follows that the vitriolic Acid decomposes all neutral salts arising from a combination of the Nitrous Acid with an earth or an Alkali. The vitriolic Acid expels the Nitrous Acid, unites with the substance which served it for a basis, and therewith forms a neutral salt, which is an Alum, a Selenites, or a vitriolated Tartar, according to the nature of that basis.

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The Nitrous Acid, when thus separated from its basis by the vitriolic Acid, is named *Spirit of Nitre*, or *Aqua Fortis*. If it be dephlegmated, or contain but little superfluous water, it exhales in reddish vapours; these vapours, being condensed and collected, form a liquor of a brownish yellow, that incessantly emits vapours of the same colour, and of a pungent disagreeable smell. These characters have procured it the names of *Smoking Spirit of Nitre*, and *Yellow Aqua Fortis*. This property in the Nitrous Acid, of exhaling in vapours, shews it to be less fixed than the vitriolic Acid; for the latter, though ever so thoroughly dephlegmated, never yields any vapours, nor has it any smell.

### §. III. Of the ACID OF SEA-SALT.

THE Acid of Sea-Salt is so called because it is in fact obtained from such Sea-Salt as is used in our kitchens. It is not certainly known in what this Acid differs from the vitriolic and the nitrous, with regard to its constituent parts. Several of the ablest Chymists, such as Becher and Stahl, are of opinion that the Marine Acid is no other than the Universal Acid united to a particular principle which they call a Mercurial Earth. Concerning this earth we shall have occasion to say more, when we come to treat of metallic substances: But in the mean time it must be owned, that the truth of this opinion is so far from being proved by a sufficient number of experiments, that the very existence of such a mercurial earth is not yet well established; and therefore, that we may not exceed the bounds of our knowledge, we shall content ourselves with delivering here the properties which characterize the Acid in question, and by which it is distinguished from the two others considered above.

When it is combined with absorbent earths, such as lime and chalk, it forms a neutral salt that  
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does not crystallize, and, when dried, attracts the moisture of the air. If the absorbent earth be not fully saturated with the Marine Acid, the salt thereby formed has the properties of a fixed Alkali: and this is what made us say, when we were on the subject of those salts, that they might be imitated by combining an earth with an Acid. The Marine Acid, like the rest, hath not so great an affinity with earths as with fixed Alkalis.

When it is combined with the latter, it forms a neutral salt which shoots into cubical crystals. This salt is inclined to grow moist in the air, and is consequently one of those which water dissolves in equal quantities; at least as to sense, whether it be boiling hot or quite cold.

The affinity of this Acid with Alkalis and absorbent Earths is not so great as that of the vitriolic and nitrous Acids with the same substances: whence it follows that, when combined therewith, it may be separated from them by either of those Acids.

The Acid of Sea-Salt, thus disengaged from the substance which served it for a basis, is called *Spirit of Salt*. When it contains but little phlegm it is of a lemon colour, and continually emits many white, very dense, and very elastic vapours; on which account it is named the *Smoking Spirit of Salt*. Its smell is not disagreeable, nor much unlike that of saffron; but extremely quick and suffocating when it smokes.

The Acid of Sea-Salt, like the other two, seems to have a greater affinity with the Phlogiston, than with fixed Alkalis. We are led to this opinion by a very curious operation, which gives ground to think that Sea-Salt may be decomposed by the proper application of a substance containing the Phlogiston.



From the Marine Acid combined with a Phlogiston results a kind of Sulphur, differing from the common sort in many respects; but particularly in this property, that it takes fire of itself upon being exposed to the open air. This combination is called *English Phosphorus*, *Phosphorus of Urine*, because it is generally prepared from urine; or, only *Phosphorus*.

This combination of the Marine Acid with a Phlogiston is not easily effected; because it requires a difficult operation in appropriated vessels. For these reasons it does not always succeed; and Phosphorus is so scarce and dear, that hitherto Chymists have not been able to make on it the experiments necessary to discover all its properties. If Phosphorus be suffered to burn away in the air, a small quantity of an acid liquor may be obtained from it, which seems to be spirit of salt, but either altered, or combined with some adventitious matter; for it has several properties that are not to be found in the pure Marine Acid; such as, leaving a fixed fusible substance behind it when exposed to a strong fire, and being easily combined with the Phlogiston so as to reproduce a Phosphorus.

Phosphorus resembles sulphur in several of its properties: it is soluble in oils; it melts with a gentle heat; it is very combustible; it burns without producing soot; and its flame is vivid and bluish.

From what has been said of the union of the Acid of Sea-Salt with a fixed Alkali, and of the neutral salt resulting therefrom, it may be concluded that this neutral salt is no other than the common kitchen-salt. But it must be observed that the fixed Alkali, which is the natural basis of the common salt obtained from sea-water, is of a sort somewhat differing from fixed Alkalies in general, and hath certain properties peculiar to itself. For,

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1. The basis of Sea-Salt differs from other fixed Alkalis in this, that it crystallizes like a neutral salt.

2. It does not grow moist in the air: on the contrary, when exposed to the air, it loses part of the water that united with it in crystallization, by which means its crystals lose their transparency, become, as it were, mealy, and fall into a fine flour.

3. When combined with the vitriolic Acid to the point of saturation, it forms a neutral salt; differing from vitriolated tartar, first, in the figure of its crystals, which are oblong six-sided solids; secondly, in its quantity of water, which in crystallization unites therewith in a much greater proportion than with vitriolated tartar; whence it follows, that this salt dissolves in water more readily than vitriolated tartar; thirdly, in that it flows with a very moderate degree of heat, whereas vitriolated tartar requires a very fierce one.

If the Acid of Sea-Salt be separated from its basis by means of the vitriolic Acid, it is easy to see that, when the operation is finished, the salt we have been speaking of must be the result. A famous Chymist, named Glauber, was the first who extracted the Spirit of Salt in this manner; examined the neutral salt resulting from his process, and, finding it to have some singular properties, called it his *Sal mirabile*, or wonderful Salt: on this account it is still called Glauber's *Sal mirabile*, or plainly *Glauber's Salt*.

4. When the basis of Sea-Salt is combined with the nitrous Acid to the point of saturation, there results a neutral salt, or a sort of nitre, differing from the common nitre, first, in that it attracts the moisture of the air pretty strongly; and this makes it difficult to crystallize: secondly, in the figure of its crystals, which are parallelopipeds; and this has procured it the name of *Quadrangular Nitre*.

Common salt, or the neutral salt formed by combining the Marine Acid with this particular sort of fixed Alkali, has a taste well known to every body. The figure of its crystals is exactly cubical. It grows moist in the air, and, when exposed to the fire, it bursts, before it melts, into many little fragments, with a crackling noise; which is called the *Decrepitation* of Sea-Salt.

That neutral salt mentioned above, which is formed by combining the Marine Acid with a common fixed Alkali, and called *Sal febrifugum Sylvii*, hath also this property.

India furnishes us with a saline substance, known by the name of *Borax*, which flows very easily, and then takes the form of glass. It is of great use in facilitating the fusion of metallic substances. It possesses some of the properties of fixed Alkalis, which has induced certain Chymists to represent it, through mistake, as a pure fixed Alkali.

By mixing borax with the vitriolic Acid, Mr. Homberg obtained from it a salt, which sublimes in a certain degree of heat, whenever such a mixture is made. This salt has very singular properties; but its nature is not yet thoroughly understood. It dissolves in water with great difficulty; it is not volatile, though it rises by sublimation from the borax. According to Mr. Rouelle's observation, it rises then only by means of the water which carries it up: for, when once made, it abides the fiercest fire, flows and vitrifies just as borax does; provided care be taken to free it previously from moisture by drying it properly. Mr. Homberg called it *Sedative Salt*, on account of its medical effects. The sedative salt hath the appearance, and some of the properties, of a neutral salt; for it shoots into crystals, and does not change the colour of violets: but it acts the part of an Acid with regard to Alkalis, uniting with them to the point of saturation, and thereby forming

ing a true neutral salt. It also acts like the Acid of vitriol on all neutral salts; that is, it discharges the Acid of such as have not the vitriolic Acid in their composition.

Since Mr. Homberg's time it hath been discovered, that a sedative salt may be made either with the nitrous or with the marine Acid; and that sublimation is not necessary to extract it from the borax, but that it may be obtained by crystallization only. For this latter discovery we are indebted to Mr. Geoffroy, as we are to Mr. Lemery for the former.

Since that time M. Baron d'Henouville, an able Chymist, hath shewn that a sedative salt may be obtained by the means of vegetable Acids; and hath lately demonstrated, in some excellent papers published in the collection of Memoirs written by the correspondents of the Academy of Sciences, that the sedative salt exists actually and perfectly in the borax, and that it is not produced by mixing Acids with that saline substance, as it seems all the Chymists before him imagined. This he proves convincingly from his analysis of borax, (which thereby appears to be nothing else but the sedative salt united with that fixed Alkali which is the basis of Sea-Salt) and from his regenerating the same borax by uniting together that Alkali and the sedative salt: a proof the most complete that can possibly be produced in natural philosophy, and equivalent to demonstration itself.

In order to finish what remains to be said upon the several sorts of saline substances, we should now speak of the Acids obtained from vegetables and animals, and also of the volatile Alkalis: but, seeing these saline substances differ from those of which we have already treated, only as they are variously altered by the unions they have contracted with certain principles of vegetables and animals, of which nothing has been yet said, it is pro-



per to defer being particular concerning them, till we have explained those principles.

## C H A P. V.

### Of L I M E.

**A**NY substance whatever, that has been roasted a considerable time in a strong fire without melting, is commonly called a *Calx*. Stones and metals are the principal subjects that have the property of being converted into *Calces*. We shall treat of Metalline *Calces* in a subsequent chapter, and in this confine ourselves to the *Calx* of *Stone*, known by the name of *Lime*.

In treating of earths in general we observed, that they may be divided into two principal kinds; one of which actually and properly flows when exposed to the action of fire, and turns to glass; whence it is called a *fusible* or *vitriifiable* earth; the other resists the utmost force of fire, and is therefore said to be an *unfusible* or *unvitriifiable* earth. The latter is also not uncommonly called *calcinable* earth; though sundry sorts of unfusible earths are incapable of acquiring by the action of fire all the qualities of *calcined* earth, or *Lime* properly so called: such earths are particularly distinguished by the denomination of *refractory* earths.

As the different sorts of stones are nothing more than compounds of different earths, they have the same properties with the earths of which they are composed, and may, like them, be divided into fusible or vitriifiable, and unfusible or calcinable. The fusible stones are generally denoted by the name of *Flints*; the calcinable stones, again, are the several sorts of marbles, cretaceous stones, those



those commonly called free-stones, &c. some of which, as they make the best Lime, are, by way of eminence, called *Lime-stones*. Sea-shells also, and stones that abound with fossile shells, are capable of being burnt to Lime.

All these substances, being exposed, for a longer or shorter time, as the nature of each requires, to the violent action of fire, are said to be *calcined*. By calcination they lose a considerable part of their weight, acquire a white colour, and become friable though ever so solid before; as, for instance, the very hardest marbles. These substances, when thus calcined, take the name of *Quick Lime*.

Water penetrates Quick Lime, and rushes into it with vast activity. If a lump of newly calcined Lime be thrown into water, it instantly excites almost as great a noise, ebullition, and smoke, as would be produced by a piece of red-hot iron; with such a degree of heat too, that, if the Lime be in due proportion to the water, it will set fire to combustible bodies; as hath unfortunately happened to vessels laden with Quick Lime, on their springing a small leak.

As soon as Quick Lime is put into water, it swells, and falls asunder into an infinite number of minute particles: in a word, it is in a manner dissolved by the water, which forms therewith a sort of white paste called *Slacked Lime*.

If the quantity of water be considerable enough for the Lime to form with it a white liquor, this liquor is called *Lac Calcis*; which, being left some time to settle, grows clear and transparent, the Lime which was suspended therein, and occasioned its opacity, subsiding to the bottom of the vessel. Then there forms on the surface of the liquor a crystalline pellicle, somewhat opaque and dark coloured, which being skimmed off is reproduced from time to time. This matter is called *Cremor Calcis*.

Slacked Lime gradually grows dry, and takes the form of a solid body, but full of cracks and destitute of firmness. The event is different when you mix it up, while yet a paste, with a certain quantity of uncalcined stony matter, such as sand for example: then it takes the name of *Mortar*, and gradually acquires, as it grows drier and older, a hardness equal to that of the best stones. This is a very singular property of Lime, nor is it easy to account for it: but it is a beneficial one; for every body knows the use of mortar in building.

Quick Lime attracts the moisture of the air, in the same manner as concentrated acids, and dry fixed alkalis; but not in such quantities as to render it fluid: it only falls into extremely small particles, takes the form of a fine powder, and the title of *Lime slacked in the air*.

Lime once slacked, however dry it may afterwards appear, always retains a large portion of the water it hath imbibed; which cannot be separated from it again but by means of a violent calcination. Being so recalcined it returns to be Quick Lime, recovering all its properties.

Besides the great affinity of Quick Lime with water, which discovers a saline character, it has several other saline properties, to be afterwards examined, much resembling those of fixed alkalis. In Chymistry it acts very nearly as those salts do, and may be considered as holding the middle rank between a pure absorbent earth and a fixed alkali: and this hath induced many Chymists to think that Lime contains a true salt, to which all the properties it possesses in common with salts may be attributed.

But as the chymical examination of this subject hath long been neglected, the existence of a saline substance in Lime hath been long doubtful. Mr. du Fay, author of some excellent chymical

mical experiments, was one of the first who obtained a Salt from Lime, by lixiviating it with a great deal of water, which he afterwards evaporated. But the quantity of salt he obtained by that means was very small; nor was it of an alkaline nature, as one would think it should have been, considering the properties of Lime. Mr. du Fay did not carry his experiments on this subject any further, probably for want of time; nor did he determine of what nature the salt was.

Mr. Malouin had the curiosity to examine this salt of Lime, and soon found that it was nothing else but what was above called *Cremor Calcis*. He found moreover, that, by mixing a fixed alkali with Lime-water, a vitriolated tartar was formed; that, by mixing therewith an alkali like the basis of sea-salt, a Glauber's salt was produced; and lastly, by combining Lime with a substance abounding in phlogiston he obtained a true sulphur. These very ingenious experiments prove to a demonstration that the vitriolic acid constitutes the salt of Lime: for, as hath been shewn, no other acid is capable of forming such combinations. On the other hand, Mr. Malouin, having forced the vitriolic acid of this salt to combine with a phlogiston, found its basis to be earthy, and analogous to that of the selenites: whence he concluded that the salt of Lime is a true neutral salt, of the same kind as the selenites. Mr. Malouin tells us he found several other salts in Lime. But as none of them was a fixed alkali, and as all the saline properties of Lime have an affinity with those of that kind of salt, there is great reason to think that all those salts are foreign to Lime, and that their union with it is merely accidental.

I myself have made several experiments in order to get some insight into the saline nature of Lime,  
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and shall here produce the result with all possible conciseness. I took several stones of different kinds, some of which produced by calcination a very strong Lime, and others but a very weak one. These I impregnated with different saline substances, acids, alkalis, and neutrals, and then exposed them all to the same degree of fire, which was a pretty strong one, and long enough continued to have made very good Lime of stones the most difficult to calcine. The consequence was, that, in the first place, those stones which naturally made but a weak Lime were not by this process converted into a stronger Lime; and, moreover, that none of these stones, even such as would naturally have produced the most active Lime, had acquired the properties of Lime. These experiments I varied many ways, employing different proportions of saline matters, and almost every possible degree of fire, and constantly observed, after calcination, that all those stones were so much the further from the nature of Lime, as they had been combined with larger doses of salts. Among those which were impregnated with the greatest proportion of salts, and had suffered the greatest violence of fire, I observed some that had begun to flow, and were in a manner vitrified. Now as the same subject cannot be, at one and the same time, in the state of glass and of Lime too; as a body cannot approach to one of these states but in proportion as it recedes from the other; and as salts in general dispose those bodies to fusion and vitrification which are in themselves the most averse to either, I concluded from my experiments, that the saline substances I used had, by acting as fluxes upon the stones, prevented their calcination; that consequently we may suspect there is no saline matter in the composition of Lime, as Lime; and that Lime does not owe its saline and alkaline properties



perties to any salt; or at least that if it does owe those properties to a salt, such salt must be naturally and originally combined with the matter of the stone in so just a proportion, that it is impossible to increase the quantity thereof without prejudicing the Lime, and depriving it in some measure of its virtue. This theory agrees perfectly with the illustrious Stahl's opinion; for he thinks, as we observed in discoursing of Salts in general, that every saline substance is but an earth combined in a certain manner with water. This notion he applies to Lime, and says that fire only subtilizes and attenuates the earthy matter, and thereby renders it capable of uniting with water in such a manner, that the result of their combination shall be a substance having saline properties; and that Lime accordingly never acquires these properties till it be combined with water.

I have dwelt longer on the Salt of Lime than I shall on any other particular; because the subject, though in itself of great importance, has hitherto been but little attended to, and because the experiments here recited are entirely new.

Lime unites with all acids, and in conjunction with them exhibits various phenomena.

The vitriolic acid poured upon Lime dissolves it with effervescence and heat. From this mixture there exhales a great quantity of vapours, in smell and colour perfectly like those of sea-salt; from which however they are found to be very different when collected into a liquor. From this combination of the vitriolic acid with Lime arises a neutral salt, which shoots into crystals, and is of the same kind with the selenitic salt obtained from Lime by Mr. Malouin.

The nitrous acid poured upon Lime dissolves it in like manner with effervescence and heat: but the solution is transparent, and therein differs from the former,

former, which is opaque. From this mixture there arises a neutral salt, which does not crystallize, and has withal the very singular property of being volatile, and rising wholly by distillation in a liquid form. This phenomenon is so much the more remarkable, as Lime, the basis of this salt, is one of the most fixed bodies known in Chymistry.

With the acid of sea-salt Lime forms also a singular sort of salt, which greedily imbibes the moisture of the air. We shall have occasion to take further notice of it in another place.

These experiments made on Lime with acids are likewise quite new. We are indebted for them to Mr. Du Hamel of the Academy of Sciences, whose admirable Memoirs on several subjects shew his extensive knowledge in all parts of Natural Philosophy.

Lime applied to fixed alkalis adds considerably to their caustic quality, and makes them more penetrating and active. An alkaline lixivium in which Lime hath been boiled, being evaporated to dryness, forms a very caustic substance, which flows in the fire much more easily, attracts and retains moisture much more strongly, than fixed alkalis that have not been so treated. An alkali thus actuated by Lime is called the *Caustic Stone*, or *Potential Caustery*; because it is employed by surgeons to produce eschars on the skin, and cauterize it.

## C H A P. VI.

*Of Metallic Substances in general.*

**M**ETALLIC Substances are heavy, glittering, opaque, fusible bodies. They consist chiefly of a vitrifiable earth united with the phlogiston.

Several Chymists insist on a third principle in these bodies, and have given it the name of *Mercurial earth*; which, according to Becher and Stahl, is the very same that being combined with the vitriolic acid forms and characterizes the acid of sea-salt. The existence of this principle hath not yet been demonstrated by any decisive experiment; but we shall shew that there are pretty strong reasons for admitting it.

We shall begin with mentioning the experiments which prove Metallic Substances to consist of a vitrifiable earth united with the phlogiston. The first is this: if they be calcined in such a manner as to have no communication with any inflammable matter, they will be spoiled of all their properties, and reduced to an earth or calx, that has neither the splendour nor the ductility of a metal, and in a strong fire turns to an actual glass, instead of flowing like a metal.

The second is, that the calx or the glass resulting from a metal thus decomposed, recovers all its metalline properties by being fused in immediate contact with an inflammable substance, capable of restoring the phlogiston of which calcination had deprived it.

On this occasion we must observe that Chymists have not yet been able, by adding the phlogiston,  
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to give the properties of metals to all sorts of vitrifiable earths indiscriminately; but to such only as originally made a part of some metallic body. For example, a compound cannot be made with the phlogiston and sand that shall have the least resemblance of a metal: and this is what seems to point out the reality of a third principle, as necessary to form the metalline combination. This principle may probably remain united with the vitrifiable earth of a metallic substance, when reduced to a glass; whence it follows, that such vitrified metals require only the addition of a phlogiston to enable them to appear again in their pristine form.

It may be inferred from another experiment, that the calx and the glass of a metal are not its pure vitrifiable earth, properly so called: for by repeated or long continued calcinations, such a calx or glass may be rendered incapable of ever resuming the metalline form, in whatever manner the phlogiston be afterwards applied to it; so that by this means it is brought into the condition of a pure vitrifiable earth, absolutely free from any mixture. Those Chymists who patronise the Mercurial earth, produce many other proofs of the existence of that principle in metallic substances; but they would be misplaced in an elementary treatise like this.

When by adding the phlogiston to a metallic glass we restore it to the form of a metal, we are said to *reduce*, *resuscitate*, or *revivify* that metal.

Metallic substances are of different kinds, and are divided into *Metals* and *Semi-metals*.

Those are called *Metals* which, besides their metalline splendour and appearance, are also malleable; that is, have the property of stretching under the hammer, and by that means of being wrought into different forms without breaking.

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Those which have only the metalline splendour and appearance, without malleability, are called Semi-metals.

Metals are also further subdivided into two sorts; viz. *Perfect* and *Imperfect* Metals.

The *Perfect* Metals are those which suffer no damage or change whatever by the most violent and most lasting action of fire.

The *Imperfect* Metals are those which by the force of fire may be deprived of their phlogiston, and consequently of their metalline form.

When but a moderate degree of fire is employed to deprive a Metal of its phlogiston, the metal is said to be *calcined*; and then it appears in the form of a powdered earth, which is called a *Calx*: and this metalline calx being exposed to a more violent degree of fire melts and turns to glass.

Metallic Substances have an affinity with acids: but not equally with all; that is, every Metallic Substance is not capable of uniting and joining with every acid.

When an acid unites with a Metallic Substance there commonly arises an ebullition, attended with a kind of hissing noise and fuming exhalations. By degrees, as the union becomes more perfect, the particles of the metal combining with the acid become invisible: this is termed *Dissolution*; and when a metalline mass thus disappears in an acid, the metal is said to be *dissolved* by that acid. It is proper to observe that acids act upon metalline substances, in one respect, just as they do upon alkalis and absorbent earths: for an acid cannot take up above such a certain proportion thereof as is sufficient to saturate it, to destroy several of its properties, and weaken others. For example, when an acid is combined with a metal to the point of saturation, it loses its taste, does not turn the blue colour of a vegetable red; and its affinity with water

is considerably impaired. On the other hand, Metalline Substances, which when pure are incapable of uniting with water, by being joined with an acid acquire the property of dissolving in water. These combinations of Metalline Substances with acids form different sorts of neutral salts; some of which have the property of shooting into crystals, while others have it not: most of them, when thoroughly dried, attract the moisture of the air.

The affinity which Metalline substances have with acids is less than that which absorbent earths and fixed alkalis have with the same acids: so that all metalline salts may be decomposed by one of these substances, which will unite with the acid, and precipitate the metal.

Metalline Substances thus separated from an acid solvent are called *Magisteries*, and *Precipitates*, of metals. None of these precipitates, except those of the perfect metals, retain the metalline form: most of their phlogiston hath been destroyed by the solution and precipitation, and must be restored before they can recover their properties. In short, they are nearly in the same state with metalline substances deprived of their phlogiston by calcination; and accordingly such a precipitate is called a *Calx*.

A metalline calx prepared in this manner loses a greater or a less portion of its phlogiston, the more or less effectually and thoroughly the metalline substance, of which it made a part, was dissolved by the acid.

Metallic Substances have affinities with each other which differ according to their different kinds: but this is not universal; for some of them are incapable of any sort of union with some others.

It must be observed that Metallic Substances will not unite, except they be both in a similar state; that is, both in a Metalline form, or both in a form  
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of a Glass; for a metalline substance retaining its phlogiston cannot contract an union with any metallic glass, even its own.

## C H A P. VII.

## Of M E T A L S.

**T**HERE are six Metals, of which two are Perfect and four Imperfect. The perfect Metals are Gold and Silver; the others are Copper, Tin, Lead, and Iron. Some Chymists admit a seventh Metal, to wit, Quick-silver: but as it is not malleable, it has been generally considered as a metallic body of a particular kind. We shall soon have occasion to examine it more minutely.

The ancient Chymists, or rather the Alchymists, who fancied a certain relation or analogy between Metals and the Heavenly Bodies, bestowed on the seven Metals, reckoning Quick-silver one of them, the names of the seven Planets of the Ancients, according to the affinity which they imagined they observed between those several bodies. Thus Gold was called *Sol*, Silver *Luna*, Copper *Venus*, Tin *Jupiter*, Lead *Saturn*, Iron *Mars*, and Quick-silver *Mercury*. Though these names were assigned for reasons merely chimerical, yet they still keep their ground; so that it is not uncommon to find the Metals called by the names, and denoted by the characters, of the Planets, in the writings even of the best Chymists. Metals are the heaviest bodies known in nature.

## §. I. Of G O L D.

G O L D is the heaviest of all Metals. The arts of wire-drawing and gold-beating shew its wonderful



derful ductility. The greatest violence of fire is not able to produce any alteration in it. Indeed Mr. Homberg, a famous Chymist, pretended that he had made this metal fume, and even vitrified it, by exposing it to the focus of one of the best burning glasses, known by the name of the Lens of the *Palais Royal*: but there are very good reasons for calling in question the experiments he made on this occasion, or rather for thinking that he was quite mistaken. For,

1. No man hath since been able to vitrify Gold, though several good Experimenters have assiduously tried to effect it, by exposing it to the focus of the same lens, and of other burning-glasses still stronger.

2. It hath been observed that though Gold, when exposed to the focus of those glasses, did indeed emit some vapours and decrease in weight; yet those vapours being carefully collected on a piece of paper, proved to be true Gold, in no degree vitrified, and which consequently had suffered no change but that of being carried away by the violence of the heat, its nature not being in the least altered.

3. The small portion of vitrified matter, which was formed on the arm that supported the Gold in Mr. Homberg's experiment, may have come either from the arm itself, or rather from some heterogeneous particles contained in the Gold; for it is almost impossible to have it perfectly pure.

4. Neither Mr. Homberg, nor any that have repeated his experiment, ever reduced this pretended glass of Gold by restoring its phlogiston, as is done with other metallic glasses.

5. To render the experiment decisive, the whole mass of Gold employed ought to have been vitrified; which was not the case.

Nevertheless I do not pretend that this metal is in its own nature absolutely indestructible, and unvitrifiable:



vitriifiable: but there is reason to think that nobody hath hitherto found the means of producing those effects on it, probably for want of a sufficient degree of fire; at least the point is very doubtful.

Gold cannot be dissolved by any pure acid: but if the acid of nitre be mixed with the acid of sea-salt, there results a compound acid liquor, with which it has so great an affinity that it is capable of being perfectly dissolved thereby. The Chymists have called this solvent *Aqua Regis*, on account of its being the only acid that can dissolve Gold, which they consider as the King of Metals. The solution of Gold is of a beautiful orange colour.

If Gold dissolved in *aqua regis* be precipitated by an alkali or an absorbent earth, the precipitate gently dried, and then exposed to a certain degree of heat, is instantly dispersed into the air, with a most violent explosion and noise: Gold thus precipitated is therefore called *Aurum Fulminans*. But if the precipitated Gold be carefully washed in plenty of water, so as to clear it of all the adhering saline particles, it will not fulminate; but may be melted in a crucible without any additament, and will then appear in its usual form. The acid of vitriol being poured on *aurum fulminans* likewise deprives it of its fulminating quality.

Gold does not begin to flow till it be red-hot like a live coal. Though it be the most malleable and most ductile of all metals, it has the singular property of losing its ductility more easily than any of them: even the fumes of charcoal are sufficient to deprive it thereof, if they come in contact with it while it is in fusion.

The malleability of this metal, and indeed of all the rest, is also considerably diminished by exposing it suddenly to cold when it is red-hot; for

example, by quenching it in water, or even barely exposing it to the cold air.

The way to restore ductility to Gold, when lost by its coming in contact with the vapour of coals, and in general to any metal rendered less malleable by being suddenly cooled, is to heat it again, to keep it red-hot a considerable time, and then to let it cool very slowly and gradually; this operation frequently repeated will by degrees much increase the malleability of a metal.

Pure sulphur hath no effect on Gold; but being combined with an alkali into a *hepar. sulphuris*, it unites therewith very readily. Nay, so intimate is their union, that the Gold by means thereof becomes soluble in water; and this new compound of Gold and liver of sulphur, being dissolved in water, will pass through the pores of brown paper without suffering any decomposition; which does not happen, at least in such a manifest degree, to other metallic substances dissolved by liver of sulphur.

*Aurum fulminans* mixed and melted with flower of sulphur loses its fulminating quality: which arises from hence, that on this occasion the sulphur burns, and its acid, which is the same with the vitriolic, being thereby set at liberty becomes capable of acting upon the Gold as a vitriolic acid would; which, as was said above, deprives the Gold of its fulminating quality.

## §. II. Of SILVER.

NEXT to Gold, Silver is the most perfect metal. Like Gold it resists the utmost violence of fire, even that in the focus of a burning-glass. However it holds only the second place among metals; because it is lighter than Gold by almost one half; is also somewhat less ductile; and lastly, because it is acted upon by a greater number of solvents.

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Yet Silver hath one advantage over Gold, namely that of being a little harder; which makes it also more sonorous.

This metal, like Gold, begins to flow when it is so thoroughly penetrated by the fire as to appear ignited like a live coal.

While this metal is in fusion, the immediate contact of the vapour of burning coals deprives it almost entirely of its malleability, in the same manner as we observed happens to Gold: but both these metals easily recover that property by being melted with nitre.

The nitrous acid is the true solvent of Silver, and being somewhat dephlegmated will very readily and easily take up a quantity of Silver equal in weight to itself.

Silver thus combined with the nitrous acid forms a metallic salt which shoots into crystals, called by the name of *Lunar Crystals*, or *Crystals of Silver*.

These crystals are most violently caustic: applied to the skin they quickly affect it much as a live coal would; they produce a blackish eschar, corroding and entirely destroying the parts they touch. Surgeons use them to eat away the proud fungous flesh of ulcers. As Silver united with the nitrous acid hath the property of blackening all animal substances, a solution of this metallic salt is employed to dye hair, or other animal matters, of a beautiful and durable black.

These crystals flow with a very moderate heat, and even before they grow red. Being thus melted they form a blackish mass; and in this form they are used by Surgeons, under the title of *Lapis Infernalis*, *Infernal Stone*, or *Lunar Caustic*.

Silver is also dissolved by the vitriolic acid: but then the acid must be concentrated, and in quantity double the weight of the Silver; nor will the solution succeed without a considerable degree of heat.



Spirit of salt and *aqua regis*, as well as the other acids, are incapable of dissolving this metal; at least in the ordinary way.

Though Silver be not soluble in the acid of sea-salt, nor easily in the acid of vitriol, as hath just been observed, it doth not follow that it hath but a weak affinity with the latter, and none at all with the former: on the contrary, it appears from experiment that it hath with these two acids a much greater affinity than with the acid of nitre: which is singular enough, considering the facility with which this last acid dissolves it.

The experiment which proves the fact, is this. To a solution of Silver in the nitrous acid, add the acid either of vitriol or of sea-salt, and the Silver will instantly quit its nitrous solvent to join with the superadded acid.

Silver thus united with the vitriolic or the marine acid is less soluble in water than when combined with the nitrous acid: and for this reason it is, that when either of these two acids is added to a solution of Silver, the liquor immediately becomes white, and a precipitate is formed, which is no other than the Silver united with the precipitating acid. If the precipitation be effected by the vitriolic acid, the precipitate will disappear upon adding a sufficient quantity of water, because there will then be water enough to dissolve it. But the case is not the same when the precipitation is made by the marine acid: for Silver combined therewith is scarce soluble in water.

This Precipitate of Silver procured by means of the marine acid is very easily fused, and when fused changes to a substance in some measure transparent and flexible; which hath occasioned it to be called by the name of *Luna Cornea*. If it be proposed to decompose this *luna cornea*, that is, to separate the marine acid from the Silver with which



it is united, the *luna cornea* must be melted along with fatty and absorbent matters, with which the acid will unite, and leave the metal exceeding pure.

It must be observed that if, instead of the marine acid, sea-salt in substance be added to a solution of Silver in the nitrous acid, a Precipitate is also produced, which by fusion appears to be a true *luna cornea*. The reason is, that the sea-salt is decomposed by the nitrous acid, which seizes its basis, as having a greater affinity therewith than its own acid hath; and this acid being consequently disengaged and set at liberty unites with the Silver, which, as has been shewn, has a greater affinity with it than with the nitrous acid. This is an instance of decomposition effected by means of one of those double affinities mentioned by us in our seventh proposition concerning Affinities.

From what hath been already said it is clear, that all these combinations of Silver with acids may be decomposed by absorbent earths, and by fixed alkalis; it being a general law with regard to all metallic substances. We shall not therefore repeat this observation when we come to treat of the other metals; unless some particular occasion require it.

With regard to Silver I must take notice that, when separated by these means from the acids in which it was dissolved, it requires nothing but simple fusion to restore it to its usual form; because it does not, any more than Gold, lose its phlogiston by those solutions and precipitations.

Silver unites with sulphur in fusion. If this metal be only made red-hot in a crucible, and sulphur be then added, it immediately flows; the sulphur acting as a flux to it. Silver thus united with sulphur forms a mass that may be cut, is half malleable, and hath nearly the colour and consistence of Lead. If this sulphurated Silver be kept a long time in fusion, and in a great degree

of heat, the sulphur flies off and leaves the Silver pure. But if the sulphur be evaporated by a violent heat, it carries off with it part of the Silver.

Silver unites and mixes perfectly with Gold in fusion. The two metals thus mixed form a compound with properties partaking of both.

Metallurgists have hitherto sought in vain for a perfectly good and easy method of separating these two metals by the *dry way* only: (this term is used to signify all operations performed by fusion:) but they are conveniently enough parted by the *moist way*, that is, by acid solvents. This method is founded on the above-mentioned properties of Gold and Silver with respect to acids. It hath been shewn that *aqua regis* only will dissolve Gold; that Silver, on the contrary, is not soluble by *aqua regis*, and that its proper solvent is the acid of nitre: consequently, when Gold and Silver are mixed together, if the compound mass be put into *aqua fortis*, this acid will take up all the Silver, without dissolving a particle of the Gold, which will therefore remain pure; and by this means the desired separation is effected. This method, which is commonly made use of by Goldsmiths and in Mints, is called the *Parting Assay*.

It is plain that if *aqua regis* were employed instead of *aqua fortis*, the separation would be equally effected; and that the only difference between this process and the former would consist in this, that now the Gold would be dissolved, and the Silver remain pure. But the operation by *aqua fortis* is preferable; because *aqua regis* does take up a little Silver, whereas *aqua fortis* hath not the least effect on Gold.

It must be observed that when Gold and Silver are mixed together in equal parts they cannot be parted by the means of *aqua fortis*. To enable the *aqua fortis* to act duly on the Silver, this metal  
must

must be, at least, in a triple proportion to the Gold. If it be in a less proportion, you must either employ *aqua regis* to make the separation, or, if you prefer the use of *aqua fortis*, melt the metalline mass, and add as much Silver as is necessary to make up the proportion above-mentioned: and hence this Process is called *Quartation*.

This effect, which is pretty singular, probably arises from hence, that when the Gold exceeds or even equals the Silver in quantity, the parts of both being intimately united, the former are capable of coating over the latter, and covering them so as to defend them from the action of the *aqua fortis*; which is not the case when there is thrice as much Silver as Gold.

There is one thing more to be taken notice of with regard to this process; which is, that perfectly pure *aqua fortis* is rarely to be met with, for two reasons; first, it is difficult in making it wholly to prevent the rising of the medium employed to disengage the nitrous acid; that is, a little of the vitriolic acid will mix with the vapours of the *aqua fortis*: secondly, unless the saltpetre be very well purified it will always hold some small portion of sea-salt, the acid of which, we know, is very readily set loose by the vitriolic acid, and consequently rises together with the vapours of the *aqua fortis*. It is easy to see that *aqua fortis* mixed either with the one or the other is not proper for the Parting Process; because, as has just been said, the vitriolic and the marine acid equally precipitate Silver dissolved in the nitrous acid; by which means, when they are united with that acid they weaken its action upon the Silver, and hinder the dissolution. Add that *aqua fortis* adulterated with a mixture of spirit of salt becomes an *aqua regis*, and consequently is rendered capable of dissolving



dissolving Gold, in proportion as its action upon Silver is diminished.

In order to remedy this inconvenience, and free *aqua fortis* from the vitriolic or marine acid with which it is tainted, Silver must be dissolved therein: by degrees as the metal dissolves, those heterogeneous acids lay hold of it, and precipitate with it in the form of a white powder, as we observed before. This precipitate being wholly fallen; the liquor grows clear; after which, if it be found capable of dissolving more Silver, without turning milky, it may be depended on as a perfectly pure *aqua fortis*. Then filtre it, dissolve more Silver in it, as long as it will take up any, and you will have a solution of Silver in a very pure *aqua fortis*. By means of this solution may other *aqua fortis* be purified: for pour a few drops thereof into a very impure *aqua fortis*, and immediately the vitriolic or marine acid, with which that *aqua fortis* is contaminated, will join the Silver and fall therewith to the bottom. When the solution of Silver prepared as above does not in the least affect the transparency of the *aqua fortis*, it is then very pure, and fit for the purposes of Quartation.

This operation of purifying *aqua fortis* by a solution of Silver is called the *Precipitation* of *aqua fortis*; and *aqua fortis* thus purified is called *Precipitated Aqua Fortis*.

When Silver is dissolved in *aqua fortis* it may be separated therefrom, as hath been shewn, by absorbent earths and fixed alkalis.

We shall see by and by that there are other means of effecting this: but whatever way it be separated from its solvent it recovers its metalline form, as Gold does, by being simply fused without any additament.



## §. III. Of COPPER.

OF all the imperfect metals Copper comes the nearest to Gold and Silver. Its natural colour is a deep red yellow. It resists a very violent degree of fire for a considerable time; but losing its phlogiston at last, it changes its metalline form for that of a calx, or a pure reddish earth. This calx is hardly, if at all, reducible to glass, without the addition of something to promote its fusion; all that the fiercest heat can do being only to render it soft. Copper, even while it retains its metalline form, and is very pure, requires a considerable degree of fire to melt it, and does not begin to flow till long after it is red-hot. When in fusion it communicates a greenish colour to the flame of the coals.

This metal is inferior to Silver in point of gravity; nor is its ductility so great, though it be pretty considerable: but, on the other hand, it exceeds that metal in hardness. It unites readily with Gold and Silver; nor does it greatly lessen their beauty when added to them in a small quantity: nay, it even procures them some advantages; such as making them harder, and less subject to lose their ductility, of which those metals are often liable to be deprived, by the mixture of the smallest heterogeneous particle. This may probably arise from hence, that the ductility of Copper has the peculiarity of resisting most of those causes which rob the perfect metals of theirs.

The property, which other metalline substances have in common with Copper, of losing the phlogiston by calcining and then vitrifying, furnishes us with a method of separating them from Gold and Silver, when they are combined therewith. Nothing more is required than to expose the mass compounded of the perfect metals and other metalline

talline substances to a degree of heat sufficient to calcine whatever is not either Gold or Silver. It is evident that by this means these two metals will be obtained as pure as is possible; for, as hath already been said, no metalline calx or glass is capable of uniting with metals possessed of their phlogiston. On this principle is formed the whole business of refining Gold and Silver.

When the perfect metals have no other alloy but Copper, as this metal is not to be calcined or vitrified without great difficulty, which is increased by its union with the unvitriifiable metals, it is easy to see that it is almost impossible to separate them without adding something to facilitate the vitrification of the Copper. Such metals as have the property of turning easily to glass are very fit for this purpose; and it is necessary to add a certain quantity thereof, when Gold or Silver is to be purified from the alloy of Copper. We shall have occasion to be more particular on this subject when we come to treat of lead.

Copper is soluble in all the acids, to which it communicates a green colour, and sometimes a blue. Even the neutral salts, and water itself, act upon this metal. With regard to water indeed, as the procuring it absolutely pure and free from any saline mixture is next to an impossibility, it remains a question whether the effect it produces on Copper be not owing to certain saline particles contained in it. It is this great facility of being dissolved that renders Copper so subject to rust; which is nothing else but some parts of its surface corroded by saline particles contained in the surrounding air and water.

The rust of Copper is always green or blue, or of a colour between these two. Internally used it is very noxious, being a real poison, as are all the solutions of this metal made by any acid whatever.

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The blue colour, which Copper constantly assumes when corroded by any saline substance, is a sure sign by which it may be discovered wherever it exists, even in a very small quantity.

Copper dissolved in the vitriolic acid forms a kind of metalline salt, which shoots into rhomboidal crystals of a most beautiful blue colour. These crystals are called *Blue Vitriol*, or *Vitriol of Copper*. They are sometimes found ready formed in the bowels of the earth; and may be artificially made by dissolving Copper in the vitriolic acid; but the solution will not succeed unless the acid be well dephlegmated. The taste of this vitriol is saltish and astringent. It retains a considerable quantity of water in crystallizing, on which account it is easily rendered fluid by fire.

It must be observed that, when it is exposed to a certain degree of heat in order to free it of its humidity, a great part of its acid flies off at the same time: and hence it is that, after calcination, there remains only a kind of earth, or metalline calx, of a red colour, which contains but very little acid. This earth cannot be brought to flow but with the greatest difficulty.

A solution of copper in the nitrous acid forms a salt which does not crystallize, but, when dried, powerfully attracts the moisture of the air. The same thing happens when it is dissolved in spirit of salt, or in *aqua regis*.

If the Copper thus dissolved by any of these acids be precipitated by an earth or an alkali, it retains nearly the colour it had in the solution: but these precipitates are scarce any thing more than the earth of Copper, or Copper deprived of most of its phlogiston; so that if they were exposed to a violent fire, without any additament, a great part of them would be converted into an earth that could never be reduced to a metalline form.

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Therefore, when we intend to reduce these precipitates to Copper, it is necessary to add a certain quantity of a substance capable of restoring to them the phlogiston they have lost.

The substance which hath been found fittest for such reductions is charcoal-dust; because charcoal is nothing but a phlogiston closely combined with an earth, which renders it exceedingly fixed, and capable of resisting a violent force of fire. But as charcoal will not melt, and consequently is capable of preventing rather than forwarding the flux of a metalline calx or glass, which nevertheless is essentially necessary to complete the reduction, it hath been contrived to mix it, or any other substance containing the phlogiston, with such fixed alkalis as easily flow, and are fit to promote the flux of other bodies. These mixtures are called *Reducing Fluxes*; because the general name of *Fluxes* is given to all salts, or mixtures of salts, which facilitate fusion.

If Sulphur be applied to Copper made perfectly red-hot, the metal immediately runs; and these two substances uniting form a new compound much more fusible than pure Copper.

This compound is destroyed by the sole force of fire, for two reasons: the first is, that, sulphur being volatile, the fire is capable of subliming a great part of it, especially when it is in a great proportion to the Copper with which it is joined; the second is, that the portion of sulphur which remains, being more intimately united with the Copper, though it be rendered less combustible by that union, is nevertheless burnt and consumed in time. Copper being combined with sulphur, and together with it exposed to the force of fire, is found to be partly changed into a blue vitriol; because the vitriolic acid, being disengaged by burning the sulphur, is by that means qualified  
to



to dissolve the Copper. The affinity of Copper with sulphur is greater than that of Silver.

This metal, as well as the other imperfect metals and the semi-metals, being mingled with nitre and exposed to the fire, is decomposed and calcined much sooner than by itself; because the phlogiston which it contains occasions the deflagration of the nitre, and consequently the two substances mutually decompose each other. There are certain metalline substances whose phlogiston is so abundant, and so weakly connected with their earth, that when they are thus treated with nitre, there arises immediately a detonation, accompanied with flame, and as violent as if sulphur or charcoal-dust had been employed; so that in a moment the metalline substance loses its phlogiston, and is calcined. The nitre, after these detonations, always assumes an alkaline character.

#### §. IV. *Of IRON.*

IRON is lighter and less ductile than Copper; but it is much harder, and of more difficult fusion.

It is the only body that has the property of being attracted by the magnet, which therefore serves to discover it wherever it is. But it must be observed that it hath this property only when in its metalline state, and loses it when converted to an earth or calx. Hence very few Iron-ores are attracted by the load-stone; because, for the most part, they are only sorts of earths, which require a phlogiston to be added before they can be brought to the form of true Iron.

When Iron hath undergone no other preparation but the fusion which is necessary to smelt it from its ore, it is usually quite brittle, and flies to pieces under the hammer: which arises in some measure from its containing a certain portion of  
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unmetallic earth interposed between its parts. This we call *Pig Iron*.

By melting this a second time it is rendered purer, and more free from heterogeneous matters: but still, as its proper parts are probably not brought sufficiently near, or closely enough united, till the Iron hath undergone some further preparation besides that of fusion, it seldom hath any degree of malleability.

The way to give it this property is to make it just red hot, and then hammer it for some time in all directions; to the end that its parts may be properly united, incorporated, and welded together, and that the heterogeneous matters which keep them asunder may be separated. Iron made by this means as malleable as possible we call *Bar Iron*, or *Forged Iron*.

Bar Iron is still harder to fuse than Pig Iron: to make it flow requires the utmost force of fire.

Iron has the property of imbibing a greater quantity of phlogiston than is necessary to give it the metalline form. It may be made to take in this superabundant phlogiston two ways: the first is by fusing it again with matters that contain the phlogiston; the second is, by encompassing it with a quantity of such matters, charcoal-dust for instance, and then exposing it so encompassed, for a certain time, to a degree of fire barely sufficient to keep it red-hot. This second method, whereby one substance is incorporated with another by means of fire, but without fusing either of them, is in general called *Cementation*.

Iron thus impregnated with an additional quantity of phlogiston is called *Steel*. The hardness of Steel may be considerably augmented by *tempering* it; that is, by making it red-hot, and suddenly quenching it in some cold liquor. The hotter the metal, and the colder the liquor in which it is quenched,

quenched, the harder will the Steel be. By this means tools are made, such as files and sheers, capable of cutting and dividing the hardest bodies, as glass, pebbles, and Iron itself. The colour of Steel is darker than that of Iron, and the facets which appear on breaking it are smaller. It is also less ductile and more brittle, especially when tempered.

As Iron may be impregnated with an additional quantity of phlogiston, and thereby converted into Steel, so may Steel be again deprived of that superabundant phlogiston, and brought back to the condition of Iron. This is effected by cementing it with poor earths, such as calcined bones and chalk. By the same operation Steel may be *untempered*: nay, it will lose the hardness it had acquired by tempering, if it be but made red-hot, and left to cool gradually. As Iron and Steel differ only in the respects we have here taken notice of, their properties being in all other respects the same, what follows is equally applicable to both.

Iron being exposed to the action of fire for some time, especially when divided into small particles, such as filings, is calcined and loses its phlogiston. By this means it turns to a kind of reddish yellow earth, which on account of its colour is called *Crocus Martis*, or *Saffron of Mars*.

This calx of Iron has the singular property of flowing in the fire with somewhat less difficulty than Iron itself; whereas every other metalline calx flows with less ease than the metal that produced it. It has moreover the remarkable property of uniting with the phlogiston, and of being reduced to Iron without fusion; requiring for that purpose only to be made red-hot.

Iron may be incorporated with Silver, and even with Gold, by means of certain operations. Under



the article of Lead we shall see how it may be separated from these metals.

The acids produce on it much the same effects as on Copper: every one of them acts upon it. Certain neutral salts, alkalis, and even water itself, are capable of dissolving it; and hence it is also very subject to rust. The vitriolic acid dissolves it with the greatest ease: but the circumstances which attend the solution thereof are different from those with which the same acid dissolves Copper: for, 1. whereas the vitriolic acid must be concentrated to dissolve Copper, it must on the contrary be diluted with water to dissolve Iron, which it will not touch when well dephlegmated. 2. The vapours which rise in this dissolution are inflammable; so that if it be made in a small-necked bottle, and the flame of a candle be applied to the mouth thereof, the vapours in the bottle take fire with such rapidity as to produce a considerable explosion.

This solution is of a beautiful green colour; and from this union of the vitriolic acid with Iron there results a neutral metalline salt, which has the property of shooting into crystals of a rhomboidal figure, and a green colour. These crystals are called *Green Vitriol*, *Vitriol of Mars*, and *Copperas*.

Green Vitriol hath a saltish and astringent taste. As it retains a great deal of water, in crystallizing it quickly flows by the action of fire: but this fluidity is owing to its water only, and is not a real fusion; for as soon as its moisture is evaporated, it resumes a solid form. Its green transparent colour is now changed into an opaque white: and, if the calcination be continued, its acid also exhales and is dissipated in vapours; and as it loses that, it turns gradually to a yellow colour, which comes so much the nearer to a red the longer the calcination is continued, or the higher the force of the fire is raised; which being driven to the utmost,  
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what remains is of a very deep red. This remainder is nothing but the body of the Iron, which having lost its phlogiston is now no more than an earth, nearly of the same nature with that which is left after calcining the metal itself.

Green Vitriol dissolved in water spontaneously lets fall a yellowish earthy sediment. If this solution be defecated by filtration, it still continues to deposit some of the same substance, till the vitriol be wholly decomposed. This sediment is nothing but the earth of Iron, which is then called *Ochre*.

The nitrous acid dissolves Iron with great ease. This solution is of a yellow colour, inclining more or less to a russet, or dark-brown, as it is more or less saturated with Iron. Iron dissolved by this acid also, falls spontaneously in a kind of calx, which is incapable of being dissolved a second time; for the nitrous acid will not act upon Iron that has lost its phlogiston. This solution does not crystallize, and if evaporated to dryness attracts the moisture of the air.

Spirit of salt likewise dissolves Iron, and this solution is green. The vapours which rise during the dissolution are inflammable, like those which ascend when this metal is attacked by the vitriolic acid. *Aqua regis* makes a solution of Iron, which is of a yellow colour.

Iron hath a greater affinity than either Silver or Copper with the nitrous and vitriolic acids: so that if Iron be presented to a solution of either in one of these two acids, the dissolved metal will be precipitated; because the acid quits it for the Iron, with which it has a greater affinity.

On this occasion it must be observed that if a solution of Copper in the vitriolic acid be precipitated by means of Iron, the precipitate has the form and splendour of a metal, and does not require the addition of a phlogiston to reduce it to true Copper;

which is not the case, as has been shewn, when the precipitation is effected by earths or alkaline salts.

The colour of this metalline precipitate hath deceived several persons, who being unacquainted with such phenomena, and with the nature of blue vitriol, imagined that Iron was transmuted into Copper, when they saw a bit of Iron laid in a solution of that vitriol become, in form and external appearance, exactly like Copper: whereas the surface only of the Iron was crufted over with the particles of Copper contained in the vitriol, which had gradually fallen upon and adhered to the Iron, as they were precipitated out of the solution.

Among the solvents of Iron we mentioned fixed alkalis; and that they have such a power is proved by the following phenomenon. If a large proportion of alkaline salts be suddenly mixed with a solution of Iron in an acid, no precipitation ensues, and the liquor remains clear and pellucid; or if at first it look a little turbid, that appearance lasts but a moment, and the liquor presently recovers its transparency. The reason is, that the quantity of alkali is more than sufficient to saturate all the acid of the solution, and the superabundant portion thereof, meeting with the Iron already finely divided by the acid, dissolves it with ease as fast as it falls, and so prevents its muddying the liquor. To evince that this is so in fact, let the alkali be applied in a quantity that is not sufficient, or but barely sufficient, to saturate the acid, and the Iron will then precipitate like any other metal.

Water also acts upon Iron; and therefore Iron exposed to moisture grows rusty. If Iron-slings be exposed to the dew, they turn wholly to a rust, which is called *Crocus Martis Aperiens*.

Iron exposed to the fire together with nitre makes it detonate pretty briskly, sets it in a flame, and decomposes it with rapidity.

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This metal hath a greater affinity than any other metalline substance with sulphur; on which account it is successively used to precipitate and separate all metalline substances combined with sulphur.

Sulphur uniting with Iron communicates to it such a degree of fusibility, that if a mass of this metal heated red-hot be rubbed with a bit of sulphur, it incessantly runs into as perfect a fusion as a metal exposed to the focus of a large burning-glass.

### §. V. Of TIN.

TIN is the lightest of all metals. Though it yields easily to the impression of hard bodies, it has but little ductility. Being bent backwards and forwards it makes a small crackling noise. It flows with a very moderate degree of fire, and long before it comes to be red-hot. When it is in fusion, its surface soon grows dusky, and there forms upon it a thin dark-coloured dusty pellicle, which is no other than a part of the Tin that has lost its phlogiston, or a calx of Tin. The metal thus calcined easily recovers its metalline form on the addition of a phlogiston. If the calx of Tin be urged by a strong fire it grows white, but the greatest violence of heat will not fuse it; which makes some Chymists consider it as a calcinable or absorbent earth, rather than a vitrifiable one. Yet it turns to glass, in some sort, when mixed with any other substance that vitrifies easily. However, it always produces an imperfect glass only, which is not at all transparent, but of an opaque white. The calx of Tin thus vitrified is called *Enamel*. Enamels are made of several colours by the addition of this or that metalline calx.

Tin unites easily with all the metals; but it destroys the ductility and malleability of every one of them, Lead excepted. Nay, it possesses this property of making metals brittle in such an eminent de-



gree, that the very vapour of it, when in fusion, is capable of producing this effect. Moreover, which is very singular, the most ductile metals, even Gold and Silver, are those on which it works this change with the most ease, and in the greatest degree. It has also the property of making Silver mixed with it flow over a very small fire.

It adheres to, and in some measure incorporates with, the surface of Copper and of Iron; whence arose the practice of coating over those metals with Tin. Tin-plates are no other than thin plates of Iron tinned over.

If to twenty parts of Tin one part of Copper be added, this alloy renders it much more solid, and the mixed mass continues tolerably ductile.

If on the contrary to one part of Tin ten parts of Copper be added, together with a little Zink, a semi-metal to be considered hereafter, from this combination there results a metalline compound, which is hard, brittle, and very sonorous; so that it is used for casting bells: this composition is called *Bronze* and *Bell-metal*.

Tin hath an affinity with the vitriolic, nitrous, and marine acids. All of them attack and corrode it; yet none of them is able to dissolve it without great difficulty: so that if a clear solution thereof be desired, particular methods must be employed for that purpose; for the acids do but in a manner calcine it, and convert it to a kind of white calx or precipitate. The solvent which has the greatest power over it is *aqua regis*, which has even a greater affinity therewith than with Gold itself; whence it follows that Gold dissolved in *aqua regis* may be precipitated by means of Tin; but then the *aqua regis* must be weakened. Gold thus precipitated by Tin is of a most beautiful colour, and is used for a red in enameling and painting on porcelain, as also to give a red colour to artificial gems. If the

the *aqua regis* be not lowered, the precipitate will not have the purple colour.

Tin hath the property of giving a great lustre to all red colours in general; on which account it is used by the dyers for striking a beautiful scarlet, and tin vessels are employed in making fine syrup of violets. Water does not act upon this metal, as it does upon Iron and Copper; for which reason it is not subject to rust: nevertheless when it is exposed to the air its surface soon loses its polish and splendour.

Tin mixed with nitre and exposed to the fire deflagrates with it, makes it detonate, and is immediately converted to a *refractory calx*: for so all substances are called which are incapable of fusion.

Tin readily unites with sulphur, and with it becomes a brittle and friable mass.

#### §. VI. Of LEAD.

NEXT to Gold and Mercury Lead is the heaviest of all metalline substances, but in hardness is exceeded by every one of them. Of all metals also it melts the easiest except Tin. While it is in fusion there gathers incessantly on its surface, as on that of Tin, a blackish dusty pellicle, which is nothing but a calx of Lead.

This calx further calcined by a moderate fire, the flame being reverberated on it, soon grows white. If the calcination be continued it becomes yellow, and at last of a beautiful red. In this state it is called *Minium*, and is used as a pigment. *Minium* is not easily made, and the operation succeeds well in large manufactures only.

To convert Lead into *Litharge*, which is the metal in a manner half vitrified, you need only keep it melted by a pretty strong fire; for then as its surface gradually calcines, it tends more and more to fusion and vitrification.

All these preparations of Lead are greatly disposed to perfect fusion and vitrification, and for that purpose require but a moderate degree of fire; the calx or earth of Lead being of all metal-line earths that which vitrifies the most easily.

Lead hath not only the property of turning into glass with the greatest facility, but it hath also that of promoting greatly the vitrification of all the other imperfect metals; and, when it is actually vitrified, procures the ready fusion of all earths and stones in general, even those which are refractory, that is, which could not be fused without its help.

Glass of Lead, besides its great fusibility, hath also the singular property of being so subtile and active as to corrode and penetrate the crucibles in which it is melted, unless they be of an earth that is exceeding hard, compact, and withal very refractory: for Glass of Lead being one of the most powerful fluxes that we know, if the earth of the crucible in which it is melted be in the smallest degree fusible, it will be immediately vitrified; especially if there be any metallic matter in its composition.

The great activity of Glass of Lead may be weakened by joining it with other vitrifiable matters: but unless these be added in a very great proportion, it will still remain powerful enough to penetrate common earths, and carry off the matters combined with it.

On these properties of Lead, and of the Glass of Lead, depends the whole business of refining Gold and Silver. It hath been shewn that as these two metals are indestructible by fire, and the only ones which have that advantage, they may be separated from the imperfect metals, when mixed therewith, by exposing the compound to a degree of fire sufficiently strong to vitrify the latter; which when  
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once converted into glass can no longer remain united with any metal that has its metalline form. But it is very difficult to procure this vitrification of the imperfect metals, when united with Gold and Silver; nay, it is in a manner impossible to vitrify them entirely, for two reasons: first, because most of them are naturally very difficult to vitrify; secondly, because the union they have contracted with the perfect metals defends them, in a manner, from the action of the fire, and that so much the more effectually as the proportion of the perfect metals is greater; which being indestructible, and in some sort coating over those with which they are alloyed, serve them as a preservative and impenetrable shield against the utmost violence of fire.

It is therefore clear that a great deal of labour may be saved, and that Gold and Silver may be refined to a much greater degree of purity than can otherwise be obtained, if to a mixture of these metals with Copper, for instance, or any other imperfect metal, be added a certain quantity of Lead. For the Lead, by its known property, will infallibly produce the desired vitrification; and as it likewise increases the proportion of the imperfect metals, and so lessens that of the perfect metals, in the mass, it evidently deprives the former of a part of their guard, and so effects a more complete vitrification. In conclusion, as the Glass of Lead hath the property of running through the crucible, and carrying with it the matters which it has vitrified, it follows that when the vitrification of the imperfect metals is effected by its means, all those vitrified matters together penetrate the vessel containing the fused metalline mass, disappear, and leave only the Gold and Silver perfectly pure, and freed, as far as is possible, from all admixture of heterogeneous parts.

The better to promote the separation of such parts, it is usual to employ in this process a particular sort  
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of small crucibles, made of the ashes of calcined bones, which are exceedingly porous and easily pervaded. They are called *cupels*, on account of their figure, which is that of a wide-mouthed cup: and from hence the operation takes its name; for when we refine Gold and Silver in this manner we are said to *cupel* those metals. It is easy to perceive that the more lead is added the more accurately will the Gold and Silver be refined; and that so much the more Lead ought to be added as the perfect metals are alloyed with a greater proportion of the imperfect. This is the most severe trial to which a perfect metal can be put; and consequently any metal that stands it may be fairly considered as such.

In order to denote the fineness of Gold, it is supposed to be divided into twenty-four parts called *carats*; that Gold which is quite pure and free from all alloy is said to be twenty-four *carats fine*; that which contains  $\frac{1}{24}$  part of alloy is called Gold of twenty-three carats; that which contains  $\frac{2}{24}$  of alloy is but twenty-two carats; and so on. Silver again is supposed to be divided into twelve parts only, which are called *penny-weights*: so that when absolutely pure it is said to be twelve *penny-weights fine*; when it contains  $\frac{1}{12}$  of alloy, it is then called eleven penny-weights fine; when it contains  $\frac{2}{12}$  of alloy, it is called ten penny-weights fine, and so on.

In treating of Copper we promised to shew, under the article of Lead, how to separate it from Iron. The process is founded on that property of Lead which renders it incapable of mixing and uniting with Iron, though it readily dissolves all other metalline substances. Therefore if you have a mass compounded of Copper and Iron, it must be fused with a certain quantity of Lead; and then the Copper, having a greater affinity with Lead than with Iron, will desert the latter and join the former, which being incapable of any union with Iron, as  
was

was said, will wholly exclude it from the new compound. The next point is to separate the Lead from the Copper; which is done by exposing the mass compounded of these two metals to a degree of fire strong enough to deprive the Lead of its metalline form, but too weak to have the same effect on the Copper: and this may be done; since of all the imperfect metals Lead is, next to Tin, the easiest to be calcined, and Copper on the contrary resists the greatest force of fire longest, without losing its metalline form. Now what we gain by this exchange, viz. by separating Copper from Iron and uniting it with Lead, consists in this, that as Lead is calcined with less fire than Iron, the Copper is less exposed to be destroyed: For it must be observed that, however moderate the fire be, it is hardly possible to prevent a certain quantity thereof from being calcined in the operation.

Lead melted with a third part of Tin forms a compound, which being exposed to a fire capable of making it thoroughly red-hot, swells, puffs up, seems in some sort to take fire, and is presently calcined. These two metals mixed together are much sooner calcined than either of them separately.

Both Lead and Tin are in some measure affected by water, and by a moist air; but they are both much less subject than Iron or Copper to be corroded by these solvents, and of course are much less liable to rust.

The vitriolic acid acts upon and dissolves Lead, much in the same manner as it doth Silver.

The nitrous acid dissolves this metal with much ease, and in great quantities; and from this solution a small portion of mercury may be obtained. On this subject see our *Elements of the Practice of Chymistry*.

When this solution of Lead is diluted with a good deal of water, the Lead precipitates in the form



form of a white powder; which happens because the acid is rendered too weak to keep the Lead dissolved.

If this solution of Lead be evaporated to a certain degree, it shoots into crystals formed like regular pyramids with square bases. These crystals are of a yellowish colour, and of a saccharine taste: they do not easily dissolve in water. This nitrous metalline salt has the singular property of detonating in a crucible, without any additament, or the contact of any other inflammable substance. This property it derives from the great quantity of phlogiston contained in, and but loosely connected with, the Lead which is one of its principles.

If spirit of salt, or even sea-salt in substance, be added to a solution of Lead in the nitrous acid, a white precipitate immediately falls; which is no other than the lead united with the marine acid. This precipitate is extremely like the precipitate of Silver made in the same manner, and that being called *Luna cornea*, hath occasioned this to be named *Plumbum corneum*. Like the *luna cornea* it is very fusible, and being melted hardens like it into a kind of horny substance: it is volatile, and may be reduced by means of inflammable matters combined with alkalis. But it differs from the *luna cornea* in this chiefly, that it dissolves easily in water; whereas the *luna cornea*, on the contrary, dissolves therein with great difficulty, and in a very small quantity.

As this precipitation of Lead from its solution in spirit of nitre is procured by the marine acid, Lead is thereby proved to have a greater affinity with the latter acid than with the former. Yet, if you attempt to dissolve Lead directly by the acid of sea-salt, the solution is not so easily effected as by the spirit of nitre, and it is always imperfect; for it wants one of the conditions essential to every solution in a liquor, namely transparency.

If Lead be boiled for a long time in a lixivium of fixed alkali, part of it will be dissolved.

Sulphur renders this metal refractory and scarce fusible; and the mass they form when united together is friable. Hence it appears that sulphur acts upon Lead much in the same manner as upon Tin; that is, it renders both these metals less fusible, which are naturally the most fusible of any, while it exceedingly facilitates the fusion of Silver, Copper, and Iron, metals which of themselves flow with the greatest difficulty.

## C H A P. VIII.

### *Of* QUICK-SILVER.

**W**E treat of Quick-silver in a chapter apart, because this metallic substance cannot be classed with the metals properly so called, and yet has some properties which will not allow us to confound it with the semi-metals. The reason why Quick-silver, by the Chymists commonly called Mercury, is not reputed a metal is, that it wants one of the essential properties thereof, to wit, malleability. When it is pure and unadulterated with any mixture, it is always fluid, and of course unmalleable. But as, on the other hand, it eminently possesses the opacity, the splendour, and above all the gravity of a metal, being next to Gold the heaviest of all bodies, it may be considered as a true metal, differing from the rest no otherwise than by being constantly in fusion; which we may suppose arises from its aptness to flow with such a small degree of heat, that be there ever so little warmth on earth, there is still more than enough to keep Mercury

cury in fusion; which would become solid and malleable if it were possible to apply to it a degree of cold considerable enough for that purpose. These properties will not allow us to confound it with the semi-metals. Add that we are not yet assured by any undoubted experiment that it can be wholly deprived of its phlogiston, as the imperfect metals may. Indeed we cannot apply the force of fire to it as could be wished: for it is so volatile that it flies off and exhales in vapours, with a much less degree of fire than is necessary to make it red-hot. The vapours of Mercury thus raised by the action of fire, being collected and united in a certain quantity, appear to be no other than true Mercury, retaining every one of its properties; and no experiment hath ever been able to shew the least change thus produced in its nature.

If Mercury be exposed to the greatest heat that it can bear without sublimation, and continued in it for several months, or even a whole year together, it turns to a red powder, which the Chymists call *Mercurius præcipitatus per se*. But to succeed in this operation it is absolutely necessary that the heat be such as is above-specified; for this metallic substance may remain exposed to a weaker heat for a considerable number of years, without undergoing any sensible alteration.

Some Chymists fancied that by this operation they had fixed Mercury and changed its nature; but without any reason: for if the Mercury thus seemingly transmuted be exposed to a somewhat stronger degree of fire, it sublimes and exhales in vapours as usual; and those vapours collected are nothing else but running Mercury, which has recovered all its properties without the help of any additament.

Mercury has the property of dissolving all the metals, Iron only excepted. But it is a condition  
absolutely



absolutely necessary to the success of such dissolution, that the metalline substances be possessed of their phlogiston; for if they be calcined, Mercury cannot touch them: and hence it follows that Mercury doth not unite with substances that are purely earthy. Such a combination of a metal with Mercury is called an *Amalgam*. Trituration alone is sufficient to effect it; however, a proper degree of heat also is of use.

Mercury amalgamated with a metal gives it a consistence more or less soft, and even fluid, according to the greater or smaller proportion of Mercury employed. All amalgams are softened by heat, and hardened by cold.

Mercury is very volatile; vastly more so than the most unfixed metals: moreover the union it contracts with any metal is not sufficiently intimate to entitle the new compound resulting from that union to all the properties of the two substances united; at least with regard to their degree of fixity and volatility. From all which it follows that the best and surest method of separating it from metals dissolved by it, is to expose the amalgam to a degree of heat sufficient to make all the Quick-silver rise and evaporate; after which the metal remains in the form of a powder, and being fused recovers its malleability. If it be thought proper to save the Quick-silver, the operation must be performed in close vessels, which will confine and collect the mercurial vapours. This operation is most frequently employed to separate Gold and Silver from the several sorts of earths and sands with which they are mixed in the ore; because these two metals, Gold especially, are of sufficient value to compensate the loss of Mercury, which is inevitable in this process: besides, as they very readily amalgamate with it, this way of separating them from every thing unmetallic is very facile and commodious.

Mercury

Mercury is dissolved by acids; but with circumstances peculiar to each particular sort of acid.

The vitriolic acid, concentrated and made boiling hot, seizes on it, and presently reduces it to a kind of white powder, which turns yellow by the affusion of water, but does not dissolve in it: it is called *Turbith Mineral*. However, the vitriolic acid on this occasion unites with a great part of the Mercury, in such a manner that the compound is soluble in water. For if to the water which was used to wash the Turbith a fixed alkali be added, there falls instantly a russet-coloured precipitate, which is no other than Mercury separated from the vitriolic acid by the intervention of the alkali.

This dissolution of Mercury by the vitriolic acid is accompanied with a very remarkable phenomenon; which is, that the acid contracts a strong smell of volatile spirit of sulphur: a notable proof that part of the phlogiston of the Mercury hath united therewith. And yet, if the Mercury be separated by means of a fixed alkali, it does not appear to have suffered any alteration. Turbith Mineral is not so volatile as pure Mercury.

The nitrous acid dissolves Mercury with ease. The solution is limpid and transparent, and as it grows cold shoots into crystals, which are a nitrous mercurial salt.

If this solution be evaporated to dryness, the Mercury remains impregnated with a little of the acid, under the form of a red powder, which hath obtained the names of *Red Precipitate*, and *Arcanum Corallinum*. This Precipitate, as well as Turbith, is less volatile than pure Mercury.

If this solution of Mercury be mixed with a solution of Copper, made likewise in the nitrous acid, and the mixture evaporated to dryness, there will remain a green powder called *Green Precipitate*.

*tate*. These precipitates are caustic and corrosive; and are used as such in surgery.

Though Mercury be dissolved more easily and completely by the nitrous acid than by the vitriolic, yet it has a greater affinity with the latter than with the former: for if a vitriolic acid be poured into a solution of Mercury in spirit of nitre, the Mercury will quit the latter acid in which it was dissolved, and join the other which was added. The same thing happens when the marine acid is employed instead of the vitriolic.

Mercury combined with spirit of salt forms a singular body; a metalline salt which shoots into long crystals, pointed like daggers. This salt is volatile, and sublimes easily without decomposition. It is moreover the most violent of all the corrosives hitherto discovered by Chymistry. It is called *Corrosive Sublimate*, because it must absolutely be sublimed to make the combination perfect. There are several ways of doing this: but the operation will never fail, if the Mercury be rarified into vapours, and meet with the marine acid in a similar state.

Corrosive Sublimate is dissolved by water, but in very small quantities only. It is decomposed by fixed alkalis, which precipitate the Mercury in a reddish yellow powder, called on account of its colour *Yellow Precipitate*.

If Corrosive Sublimate be mixed with tin, and the compound distilled, a liquor comes over which continually emits abundance of dense fumes, and from the name of its inventor is called the *Smoking Liquor of Libavius*. This liquor is no other than the tin combined with the marine acid of the Corrosive Sublimate, which therefore it hath actually decomposed: whence it follows that this acid hath a greater affinity with tin than with Mercury.

The marine acid in Corrosive Sublimate is not quite saturated with Mercury; but is capable of



taking up a much greater quantity thereof. For if Corrosive Sublimate be mixed with fresh Mercury, and sublimed a second time, another compound will be produced containing much more Mercury, and less acrimonious; for which reason it is named *Sweet Sublimate of Mercury, Mercurius dulcis, Aquila alba*. This compound may be taken internally, and is purgative or emetic according to the dose administered. It may be rendered still more gentle by repeated sublimations, and then it takes the title of *Panacea Mercurialis*. No way hath hitherto been found to dissolve Mercury in *aqua regis* without great difficulty, and even then it is but imperfectly dissolved.

Mercury unites easily and intimately with sulphur. If these two substances be only rubbed together in a gentle heat, or even without any heat, they will contract an union, tho' but an incomplete one. This combination takes the form of a black powder, which has procured it the name of *Æthiops Mineral*.

If a more intimate and perfect union be desired, this compound must be exposed to a stronger heat; and then a red ponderous substance will be sublimed, appearing like a mass of shining needles; this is the combination desired, and is called *Cinabar*. In this form chiefly is Mercury found in the bowels of the earth. Cinabar finely levigated acquires a much brighter red colour, and is known to painters by the name of *Vermilion*.

Cinabar rises wholly by sublimation, without suffering any decomposition; because the two substances of which it consists, viz. Mercury and Sulphur, are both volatile.

Though Mercury unites and combines very well with sulphur, as hath been said, yet it hath less affinity with that mineral than any other metal;—Gold only excepted: whence it follows that any of the other metals will decompose Cinabar, by  
uniting

uniting with its sulphur, and so setting the Mercury at liberty to appear in its usual form. Mercury thus separated from sulphur is esteemed the purest, and bears the name of *Mercury revived from Cinabar*.

Iron is generally used in this operation, preferably to the other metals, because among them all it has the greatest affinity with sulphur, and is the only one that has none with Mercury.

Cinabar may also be decomposed by means of fixed alkalis; the affinity of these salts with sulphur being generally greater than that of any metalline substance whatever.

## C H A P. IX.

### *Of the SEMI-METALS.*

#### §. I. *Of REGULUS OF ANTIMONY.*

**R**EGULUS of Antimony is a metallic substance of a pretty bright white colour. It has the splendour, opacity, and gravity of a metal: but it is quite unmalleable, and crumbles to dust, instead of yielding or stretching, under the hammer; on which account it is classed with the Semi-metals.

It begins to flow as soon as it is moderately red; but, like the other Semi-metals, it cannot stand a violent degree of fire; being thereby dissipated into smoke and white vapours, which adhere to such cold bodies as they meet with, and so are collected into a kind of *farina* called *Flowers of Antimony*.

If Regulus of Antimony, instead of being exposed to a strong fire, be only heated so moderately that it shall not even melt, it will calcine, lose its phlogiston, and take the form of a greyish powder

powder destitute of all splendour : this powder is called *Calx of Antimony*.

This calx is not volatile like the Regulus, but will endure a very violent fire ; and being exposed thereto will flow, and turn to a glass of the yellowish colour of a hyacinth.

It is to be observed that the more the Regulus is deprived of its phlogiston by continued calcination, the more refractory is the calx obtained from it. The glass thereof has also so much the less colour, and comes the nearer to common glass.

The calx and the Glass of Antimony will recover their metalline form, like every other Calx and Glass of a metal, if reduced by restoring to them their lost phlogiston. Yet if the calcination be carried too far, their reduction will become much more difficult, and a much smaller quantity of Regulus will be resuscitated.

Regulus of Antimony is capable of dissolving the metals ; but its affinities with them are various, and differ according to the following order. It affects Iron the most powerfully, next Copper, then Tin, Lead, and Silver. It promotes the fusion of metals, but makes them all brittle and unmalleable.

It will not amalgamate with Mercury ; and though by certain processes, particularly the addition of water and continued trituration, a sort of union between these two substances may be produced, yet it is but apparent and momentary ; for being left to themselves, and undisturbed, they quickly disunite and separate \*.

\* M. Malouin, however, hath found a way to unite these two metallic substances : but then he does it by the interposition of sulphur ; that is, he combines crude Antimony with Mercury. This combination is brought about in the same way that *Æthiops Mineral* is made ; viz. either by fusion or by trituration only without fire. It resembles the common *Æthiops*, and M. Malouin calls it *Æthiops of Antimony*. He observed that Mercury unites with Antimony much more intimately, by melting, than by rubbing them together.

The



The vitriolic acid, assisted by heat, and even by distillation, dissolves Regulus of Antimony. The nitrous acid likewise attacks it; but the solution can by no art be made clear and limpid: so that the Regulus is only calcined, in a manner, by this acid.

The marine acid dissolves it well enough; but then it must be exceedingly concentrated, and applied in a peculiar manner, and especially by distillation. One of the best methods of procuring a perfect union between the acid of sea-salt and Regulus of Antimony, is to pulverize the latter, mix it with corrosive sublimate, and distil the whole. There rises in the operation a white matter, thick and scarce fluid, which is no other than the Regulus of Antimony united and combined with the acid of sea-salt. This compound is extremely corrosive, and is called *Butter of Antimony*.

It is plain that the corrosive sublimate is here decomposed; that the Mercury is revived, and that the acid which was combined therewith hath quitted it to join the Regulus of Antimony, with which its affinity is greater. This Butter of Antimony by repeated distillations acquires a considerable degree of fluidity and limpidness.

If the acid of nitre be mixed with Butter of Antimony, and the whole distilled, there rises an acid liquor, or a sort of *aqua regis*, which still retains some of the dissolved Regulus, and is called *Bezoardic Spirit of Nitre*. After the distillation there remains a white matter, from which fresh spirit of nitre is again abstracted, and which being then washed with water is called *Bezoar Mineral*. This Bezoar Mineral is neither so volatile, nor so caustic, as Butter of Antimony; because the nitrous acid hath not the property of volatilizing metallic substances, as the marine acid does, and because it remains much more intimately combined with the reguline part.

If Butter of Antimony be mixed with water, the liquor immediately becomes turbid and milky, and a precipitate falls, which is nothing but the metallic matter partly separated from its acid, which is too much weakened by the addition of water to keep it dissolved. Yet this precipitate still retains a good deal of acid; for which reason it continues to be a violent emetic, and in some degree corrosive. It hath therefore been very improperly called *Mercurius Vitæ*.

The proper solvent of Regulus of Antimony is *aqua regis*; by means whereof a clear and limpid solution of this Semi-metal may be obtained.

Regulus of Antimony mixed with nitre, and projected into a red-hot crucible, sets the nitre in a flame, and makes it detonate. As it produces this effect by means of its phlogiston, it must needs at the same time be calcined, and lose its metallic properties, which accordingly happens, and when the nitre is in a triple proportion to the Regulus, the latter is so perfectly calcined as to leave only a white powder, which is fused with great difficulty, and then turns to a faintly coloured glass, not very different from common glass, and which is not reducible to a Regulus by the addition of inflammable matter; at least it yields but a very small quantity thereof. If less nitre be used, the calx is not so white; the glass it produces is more like a metal-line glass, and is more easily reduced. The calx of the Regulus thus prepared by nitre is called, on account of the medicinal virtue ascribed to it, *Diaphoretic Antimony*, or *Diaphoretic Mineral*.

Nitre always becomes an alkali by deflagration, and in the present case retains part of the calx, which it even renders soluble in water. This calx may be separated from the alkali, if an acid be employed to precipitate it; and then it is called *Materia Perlata*. This pearly matter is a calx of Antimony,

mony, so completely deprived of its phlogiston as to be altogether incapable of reduction to a Regulus.

Regulus of Antimony readily joins and unites with sulphur, forming therewith a compound which has a very faint metallic splendour. This compound appears like a mass of long needles adhering together laterally; and under this form it is usually found in the ore, or at least when only separated by fusion from the stones and earthy matters with which the ore is mixed. It is called *Crude Antimony*.

Antimony flows with a moderate heat, and becomes even more fluid than other metallic substances. The action of fire dissipates or consumes the sulphur it contains, and its phlogiston also, so as to convert it into a calx and a glass, as it does the Regulus.

*Aqua regis*, which we observed to be the proper solvent of the Regulus, being poured on Antimony, attacks and dissolves the reguline part, but touches not the sulphur; in consequence whereof it decomposes the Antimony, and separates its sulphur from its Regulus.

There are several other ways of effecting this decomposition, and obtaining the reguline part of Antimony by itself: they consist either in destroying the sulphureous part of the Antimony by combustion, or in melting the Antimony with some substance, which has a greater affinity than its reguline part with sulphur. Most metals are very fit for this latter purpose: for though the Regulus has a considerable affinity with sulphur, yet all the metals, except Gold and Mercury, have a greater.

If therefore Iron, Copper, Lead, Silver, or Tin, be melted with Antimony, the metal employed will unite with the sulphur, and separate it from the Regulus.



It must be observed that, as these metals have some affinity with the Regulus of Antimony, the Regulus will be joined in the operation by some of the metal employed as a *Precipitant*, (so those substances are called which serve as the means of separating two bodies from each other;) and therefore the Regulus procured in this manner will not be absolutely pure: on this account care is taken to distinguish each by adding the name of the metal employed in its precipitation; and thence come these titles, *Martial Regulus of Antimony*, or only *Martial Regulus*, *Regulus Veneris*; and so of the rest.

Antimony is employed with advantage to separate Gold from all the other metals with which it may be alloyed. It has been shewn that all the metals have a greater affinity, than the reguline part of Antimony, with sulphur, Gold only excepted; which is incapable of contracting any union therewith: and therefore, if a mass compounded of Gold and several other metals be melted with Antimony, every thing in that mass which is not Gold will unite with the sulphur of the Antimony. This union occasions two separations, to wit, that of the sulphur of the Antimony from its reguline part, and that of the Gold from the metals with which it was adulterated; and from the whole two new compounds arise; namely, a combination of the metals with the sulphur, which being lightest rises to the surface in fusion; and a metalline mass formed of the Gold and the reguline part of the Antimony united together, which being much the heaviest sinks to the bottom. There is no difficulty in parting the Gold from the Regulus of Antimony with which it is alloyed: for the metalline mass need only be exposed to a degree of fire capable of dissipating into vapours all the Semi-metal it contains; which being very volatile, the operation is much easier, and more expeditiously finished, than if the metals with which the

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the Gold was debased were to be vitrified on the cupel; without taking into the account that if Silver were one of them, recourse must needs be had to the process of quartation after that of the cupel.

If equal parts of nitre and Antimony be mixed together, and the mixture exposed to the action of fire, a violent detonation ensues; the nitre deflagrating consumes the sulphur of the Antimony, and even a part of its phlogiston. After the detonation there remains a greyish matter which contains fixed nitre, vitriolated tartar, and the reguline part of the Antimony in some measure deprived of its phlogiston, and half vitrified by the action of the fire, which is considerably increased by the deflagration. This matter is called *Liver of Antimony*.

If instead of equal parts of nitre and Antimony, two parts of the former be used to one of the latter, then the reguline part loses much more of its phlogiston, and remains in the form of a yellowish powder.

Again, if three parts of nitre be taken to one of Antimony, the Regulus is thereby entirely robbed of its phlogiston, and converted to a white calx which bears the name of *Diaphoretic Antimony*, or *Diaphoretic Mineral*. The pearly matter may be precipitated by pouring an acid on the saline substances which here remain after the detonation, in the same manner as we shewed above was to be done with regard to the Regulus.

In the two last operations, where the nitre is in a double or triple proportion to the Antimony, the reguline part is found after the detonation to be converted into a calx, and not into a half vitrified matter, which we have seen is the effect when equal parts only of nitre and Antimony are used. The reason of this difference is, that in these two cases the reguline part, being wholly, or almost wholly, deprived of its phlogiston, becomes, as was observed,  
more

more difficult to fuse, and consequently cannot begin to vitrify in the same degree of heat as that which hath not lost so much of its phlogiston. If instead of performing the operation with equal parts of nitre and Antimony alone, a portion of some substance which abounds with phlogiston be added, in that case the sulphur only of the Antimony will be consumed, and the Regulus will remain united with its phlogiston and separated from its sulphur.

The Regulus prepared in this manner is absolutely pure, because no metalline substance being employed, none can mix with and adulterate it. It is called *Regulus of Antimony per se*, or only *Regulus of Antimony*.

It is true indeed that in this operation much of the reguline part unavoidably loses its phlogiston and is calcined, and consequently a much smaller quantity of Regulus is obtained than when metalline precipitants are employed; but this loss is easily repaired, if it be thought proper, by restoring to the calcined part its lost phlogiston.

Antimony melted with two parts of fixed alkali yields no Regulus, but is entirely dissolved by the salt, and forms with it a mass of a reddish yellow colour.

The reason why no precipitate is produced on this occasion is, that the alkali uniting with the sulphur of the Antimony forms therewith the combination called Liver of Sulphur, which by its nature is qualified to keep the reguline part dissolved. This mass formed by the union of the Antimony with the alkali is soluble in water. If any acid whatever be dropt into this solution, there falls a precipitate of a reddish yellow colour; because the acid unites with the alkali, and forces it to quit the matters with which it was combined. This precipitate is called *Golden Sulphur of Antimony*.



As in the operation for preparing *Regulus of Antimony per se*, some of the nitre is, by the inflammable matters added thereto, turned to an alkali, this alkali seizes on part of the Antimony, and therewith forms a compound like that just described. Hence it comes that if the scoria formed in this process be dissolved in water, and an acid dropped into the solution, a true golden sulphur of Antimony is thereby separated.

This union of Antimony with an alkali may also be brought about by the humid way; that is, by making use of an alkali resolved into a liquor, and boiling the mineral in it. The alkaline liquor, in proportion as it acts upon the Antimony, gradually becomes reddish and turbid. If left to settle and cool when well saturated therewith, it gradually deposits the Antimony it had taken up, which precipitates in the form of a red powder: and this precipitate is the celebrated remedy known by the name of *Kermes Mineral*. It is plain that the kermes is nearly the same thing with the golden sulphur; yet it differs from it in some respects; and especially in this, that being taken inwardly it operates much more gently than the golden sulphur, which is a violent emetic. Nitre fixed by charcoal, and resolved into a liquor, is the only alkali employed in preparing the kermes.

It was shewn above that *Regulus of Antimony* mixed and distilled with corrosive sublimate decomposes it, disengages the Mercury, and joining itself to the marine acid forms therewith a new combination, called *Butter of Antimony*. If the same operation be performed with crude Antimony instead of its *Regulus*, the same effects are produced: but then the Antimony itself is also decomposed; that is, the reguline part is separated from the sulphur, which being set free unites with the Mercury, now also at liberty, and these

two together form a true cinabar called *Cinabar of Antimony*.

## §. II. Of BISMUTH.

BISMUTH, known also by the name of Tin-glass, is a semi-métal, having almost the same appearance as Regulus of Antimony; yet it has a more dusky cast, inclining somewhat to red, and even presents some changeable streaks, especially after lying long in the air.

When exposed to the fire it melts long before it is red, and consequently with less heat than Regulus of Antimony, which does not flow, as was shewn above, till it begin to be red-hot. It becomes volatile, like all the other semi-metals, when acted on by a violent fire; being kept in fusion by a proper degree of heat it loses its phlogiston with its metallic form, and turns to a powder or a calx; and that again is converted into glass by the continued action of fire. The calx and glass of Bismuth may be reduced, like any other metallic calx, by restoring their phlogiston.

Bismuth mixes with all the metals in fusion, and even facilitates the fusion of such as do not otherwise flow readily. It whitens them by its union, and destroys their malleability.

It amalgamates with Mercury, if they be rubbed together with the addition of water: yet after some time these two metalline substances desert each other, and the Bismuth appears again in the form of a powder. Hence it is plain that the union it contracts with Mercury is not perfect; and yet it has the singular property of attenuating Lead, and altering it in such a manner that it afterwards amalgamates with Mercury much more perfectly, so as even to pass with it through shamoy leather without any separation. The Bismuth employed in making this amalgama afterwards separates from it spontaneously,

neously, as usual; but the Lead still continues united with the Mercury, and always retains the property thus acquired.

The vitriolic acid does not dissolve Bismuth: its proper solvent is the nitrous acid, which dissolves it with violence, and abundance of fumes.

Bismuth dissolved in the nitrous acid is precipitated not only by alkalis, but even by the bare addition of water. This precipitate is extremely white, and known by the name of *Magistery of Bismuth*.

The acid of sea-salt and *aqua regis* likewise act upon Bismuth, but with less violence.

This semi-metal does not sensibly deflagrate with nitre; yet it is quickly deprived of its phlogiston, and turned into a vitrifiable calx, when exposed with it to the action of fire.

It readily unites with sulphur in fusion, and forms therewith a compound which appears to consist of needles adhering laterally to each other.

It may be separated from the sulphur with which it is combined, by only exposing it to the fire, without any additament; for the sulphur is either consumed or sublimed, and leaves the Bismuth behind.

### §. III. Of ZINC.

ZINC to appearance differs but little from Bismuth, and has even been confounded with it by several authors. Nevertheless, besides that it has something of a blueish cast, and is harder than Bismuth, it differs from it essentially in its properties, as will presently be shewn. These two metallic substances scarce resemble each other in any thing, but the qualities common to all semi-metals.

Zinc melts the moment it grows red in the fire, and then also begins to turn to a calx, which, like any other metallic calx, may be reduced by means of the phlogiston: but if the fire be considerably increased,



increased, it sublimes, flames, and burns like an oily matter; which is a proof of the great quantity of phlogiston in its composition. At the same time abundance of flowers rise from it in the form of white flakes, flying about in the air like very light bodies; and into this form may the whole substance of the Zinc be converted. Several names have been given to these flowers, such as Pompholyx, Philosophic Wool. They are supposed to be no other than the Zinc itself deprived of its phlogiston; yet nobody has hitherto been able to resuscitate them in the form of Zinc, by restoring their phlogiston according to the methods used in the reduction of metals. Though they rise in the air with very great ease while the Zinc is calcining, yet when once formed they are very fixed; for they withstand the utmost violence of fire, and are capable of being vitrified, especially if joined with a fixed alkali. They are soluble in acids.

Zinc unites with all metalline substances, except Bismuth. It has this singular property, that being mixed with Copper, even in a considerable quantity, such as a fourth part, it does not greatly lessen the ductility thereof, and at the same time communicates to it a very beautiful colour not unlike that of Gold: on which account the composition is frequently made, and produces what is called *Brass*. This metal melts much more easily than Copper alone, because of the Zinc with which it is alloyed. If it be exposed to a great degree of heat, the Zinc which it contains takes fire, and sublimes in white flowers, just as when it is pure.

It is to be observed that Brass is ductile only when it is cold, and not then unless the Zinc used in making it was very pure; otherwise the composition will prove but a *Tombac* or *Prince's Metal*, having very little malleability.

Zinc

Zinc is very volatile, and carries off with it any metallic substance with which it is fused, making a kind of sublimate thereof. In the furnaces where they smelt ores containing Zinc, the matter thus sublimed is called *Cadmia Fornacum*, to distinguish it from the native *Cadmia* called also *Calamine*, or *Lapis Calaminaris*; which, properly speaking, is an ore of Zinc, containing a great deal of that semi-metal, together with some Iron, and a stony substance. The name of *Cadmia Fornacum* is not appropriated solely to the metallic sublimes procured by means of Zinc, but is given in general to all the metallic sublimes found in smelting-houses.

If a violent and sudden heat be applied to Zinc, it sublimes in its metalline form; there not being time for it to burn and be resolved into flowers.

This semi-metal is soluble in all the acids, but especially in spirit of nitre, which attacks and dissolves it with very great violence.

Zinc has a greater affinity than iron or copper with the vitriolic acid; and therefore it decomposes the green and blue vitriols, precipitating those two metals by uniting with the vitriolic acid, with which it forms a metallic salt, or vitriol, called *White Vitriol*, or *Vitriol of Zinc*.

Nitre mixed with Zinc, and projected into a red-hot crucible, detonates with violence, and during the detonation there rises a great quantity of white flowers, like those which appear when it is calcined by itself.

Sulphur has no power over Zinc. Even liver of sulphur, which dissolves all other metallic substances, contracts no union with this semi-metal.

Mess. Hellot and Malouin have bestowed a great deal of pains on this semi-metal. An account of their experiments is to be found in the Memoirs of the Academy of Sciences.

## §. IV. Of REGULUS OF ARSENIC.

REGULUS of Arsenic is the most volatile of all the semi-metals. A very moderate heat makes it wholly evaporate, and fly off in fumes; on which account it cannot be brought to fusion, nor can any considerable masses thereof be obtained. It has a metallic colour, somewhat resembling Lead; but it soon loses its splendour when exposed to the air.

It unites readily enough with metallic substances, having the same affinities with them as Regulus of Antimony hath. It makes them brittle, and unmal-leable. It hath also the property of rendering them volatile, and greatly facilitates their scorification.

It very easily parts with its phlogiston and its metallic form. When exposed to the fire it rises in a kind of shining crystalline calx, which on that account looks more like a saline matter than a metallic calx. To this calx or these flowers are given the names of *White Arsenic*, *Crystalline Arsenic*, and most commonly plain *Arsenic*.

The properties of this substance are very singular, and extremely different from those of any other metallic calx. Hitherto it hath been but little examined; and this led me to make some attempts towards discovering its nature, which may be seen in the Memoirs of the Academy of Sciences.

Arsenic differs from every other metalline calx, first, in being volatile; whereas the calxes of all other metallic substances, not excepting those of the most volatile semi-metals, such as Regulus of Antimony and Zinc, are exceedingly fixed; and secondly, in having a saline character, which is not found in any other metalline calx.

The saline character of Arsenic appears, first, from its being soluble in water; secondly, from its corrosive quality, which makes it one of the most violent



violent poisons: a quality from which the other metallic substances are free, when they are not combined with some saline matter. Regulus of Antimony must however be excepted. But then the best Chymists agree that this semi-metal is either nearly of the same nature with Arsenic, or contains a portion thereof in its composition: besides, its noxious qualities never discover themselves so plainly as when it is combined with some acid. Lastly, Arsenic acts just like the vitriolic acid upon nitre; that is, it decomposes that neutral salt, by expelling its acid from its alkaline basis, of which it takes possession, and therewith forms a new saline compound.

This combination is a species of salt that is perfectly neutral. When the operation is performed in a close vessel, the salt shoots into crystals in the form of right-angled quadrangular prisms, terminated at each extremity by pyramids that are also quadrangular and right-angled; some of which however, instead of ending in a point, are obtuse as if truncated. The consequence is different when the operation is performed in an open vessel; for then nothing is obtained but an alkaline salt impregnated with Arsenic, which cannot be crystallized.

The cause of this different effect is that, when the Arsenic is once engaged in the alkaline basis of the nitre, it can never be separated from it by the utmost force of fire, so long as it is kept in a close vessel; whereas, if you expose it to the fire without that precaution, it readily separates from it. This property of Arsenic was never before observed by any Chymist, and therefore this our new species of Neutral arsenical salt was absolutely unknown till lately.

This new salt possesses many singular properties, the chief of which are these. First, it cannot be

decompounded by the intervention of any acid, even the strongest acid of vitriol; and this, joined to its property of expelling the nitrous acid from its basis, shews that it has a very great affinity with fixed alkalis.

Secondly, this very salt, on which pure acids have no effect, is decompounded with the greatest ease by acids united with metallic substances. The reason of this phenomenon is curious, and furnishes us with an instance of what we advanced concerning double affinities.

If to a solution of any metallic substance whatever, made by any acid whatever, (except that of Mercury by the marine acid, and that of Gold by *aqua regis*), a certain quantity of our New Salt dissolved in water be added, the metallic substance is instantaneously separated from the acid in which it was dissolved, and falls to the bottom of the liquor.

All metallic precipitates obtained in this manner are found to be a combination of the metal with Arsenic; whence it necessarily follows that the new Neutral Salt is by this means decompounded, its arsenical part uniting with the metallic substance, and its alkaline basis with the acid in which that substance was dissolved.

The affinities of these several bodies must be considered as operating on this occasion in the following manner: The acids which tend to decompound the Neutral Salt of Arsenic, by virtue of their affinity with its alkaline basis, are not able to accomplish it, because this affinity is powerfully counteracted by that which the Arsenic has with the same alkaline basis, and which is equal or even superior to theirs. But if these acids happen to be united with a substance which naturally has a very great affinity with the arsenical part of the Neutral Salt, then, the two parts of which this Salt consists being drawn different ways by two several affinities tending to se-  
parate

parate them from each other, the Salt will undergo a decomposition, which could not have been effected without the help of this second affinity. Now as metallic substances have a great affinity with Arsenic, it is not surprising that the Neutral Salt of Arsenic, which cannot be decomposed by a pure acid, should nevertheless yield to an acid combined with a metal. The decomposition of this Salt, therefore, and the precipitation which of course it produces in metallic solutions, are brought about by the means of a double affinity; namely, that of the acid with the alkaline basis of the Neutral Salt, and that of the metal with the arsenical part of that salt.

Arsenic has not the same effect on sea-salt as on nitre, and cannot expel its acid: a very singular phenomenon, for which it is hard to assign a reason; for the nitrous acid is known to have a greater affinity than the marine acid with alkalis, and even with the basis of sea-salt itself.

Yet Arsenic may be combined with the basis of sea-salt, and a Neutral salt thereby obtained, like that which results from the decomposition of nitre by Arsenic: but for that purpose a quadrangular nitre must be first prepared, and Arsenic applied thereto as to common nitre.

The Salt produced by uniting Arsenic with the basis of sea-salt very much resembles the Neutral salt of Arsenic above treated of, as well in the figure of its crystals as in its several properties.

Arsenic presents another singular phenomenon, both with the alkali of nitre and with that of sea-salt; which is, that if it be combined with these salts in a fluid state, it forms with them a saline compound, quite different from the Neutral salts of arsenic which result from the decomposition of nitrous salts.

This saline compound, which I call *Liver of Arsenic*, takes up a much greater quantity of Arsenic



than is necessary for the perfect saturation of the alkali. It has the appearance of a glue, which is so much the thicker the more Arsenic it contains. Its smell is disagreeable; it attracts the moisture of the air, and does not crystallize; it is easily decomposed by any acid whatever, which precipitates the Arsenic and unites with the alkali. Lastly, the effects it produces on metallic solutions are different from those of our neutral arsenical salts. But the bounds which I have set myself in this treatise will not allow me to be more particular. Such as have the curiosity to enquire further into the subject may consult my *Dissertations on Arsenic*, published among the *Memoirs of the Academy of Sciences*.

Arsenic is easily reduced to a *Regulus*. It need only be mixed with any matter containing the phlogiston, and by the help of a moderate heat a true *Regulus* will sublime. This *Regulus*, as was said, is very volatile, and calcines with the greatest ease; which is the reason why it cannot be obtained but in small quantities, and also why, in order to obtain masses of it, some have thought of adding thereto some metal with which it has a great affinity, such as Copper or Iron; because by joining with the metal it is partly fixed and restrained from flying off. But it is plain the *Regulus* obtained by this means is not pure, as it must partake considerably of the metal employed.

Arsenic readily unites with sulphur, and rises with it in a yellow compound called *Orpiment*.

Sulphur cannot be separated from Arsenic but by the intervention of two bodies only; to wit, a fixed alkali and Mercury.

The property which Mercury possesses of separating sulphur from Arsenic is founded on this, that these two metallic substances are incapable of contracting any union; whereas though most of the other metals and semi-metals have a greater affinity

with sulphur than Mercury hath, as was shewn in treating of the decomposition of Cinabar, nevertheless they are all unable to decompose Orpiment; because some of them have as great an affinity with Arsenic as with sulphur; others have no affinity with either; and lastly, sulphur hath as great an affinity with Arsenic as with any of them.

It must be observed that, if fixed alkalis be employed to purify Arsenic in this manner, no more must be used than is necessary to absorb the sulphur or the phlogiston, of which also it is their nature to deprive Arsenic; for otherwise, as it has been shewn, that Arsenic readily unites with alkalis, they would absorb a considerable quantity thereof.

## C H A P. X.

*Of OIL in general.*

**O**IL is an unctuous body, which burns and consumes with flame and smoke, and is not soluble in water. It consists of the phlogiston united with water by means of an acid. There is moreover in its composition a certain proportion of earth, more or less according to each several sort of Oil.

The inflammability of Oil evidently proves that it contains the phlogiston. That an acid is one of its constituent principles many experiments demonstrate, of which these are the chief: If certain Oils be long triturated with an alkaline salt, and the alkali afterwards dissolved in water, crystals of a true neutral salt will be produced: some metals, and particularly Copper, are corroded and rusted by Oils, just as they are by acids: again, acid crystals

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are found in some Oils that have been long kept. This acid in Oil serves undoubtedly to unite its phlogiston with its water; because these two substances having no affinity with each other cannot be united without the intervention of such a medium as an acid, which has an affinity with both. As to the existence of water in Oils, it appears plainly when they are decomposed by repeated distillations, especially after mixing them with absorbent earths. Lastly, when an Oil is destroyed by burning, a certain quantity of earth is constantly left behind.

We are very sure that the abovementioned principles enter into the composition of Oils; for they may be obtained from every one of them: but it is not absolutely certain that they consist of these only, and that they do not contain some other principle which may escape our notice in decomposing them; for hitherto it doth not appear, by any experiment we can depend on, that Oil was ever produced by combining together the principles here specified: yet such redintegrations are the only means we have of satisfying ourselves that we know all the principles which constitute a body.

Oils exposed to the fire in close vessels, pass over almost wholly from the containing vessel into any other applied to receive them. There remains, however, a small quantity of black matter, which is extremely fixed, and continues unalterable as long as it hath no communication with the external air, be the force of the fire ever so violent. This matter is no other than part of the phlogiston of the Oil united with its most fixed and grossest earth; and this is what we called *Charcoal*, or plainly a *Coal*.

### §. I. Of CHARCOAL.

WHEN Oil happens to be united to much earth, as it is in vegetable and animal bodies, it leaves a considerable quantity of *Coal* or Charred matter. This



This Coal, exposed to the fire in the open air, burns and wastes, but without blazing like other combustible matters: there appears only a small blueish flame, but not the least smoke. Most commonly it only glows and sparkles, and so gradually falls into ashes, which are nothing but the earth of the body, combined with an alkaline salt in burning. This alkaline salt may be separated from the earth, by lixiviating the ashes with water, which dissolves all the salt, and leaves the earth quite pure.

Charcoal is unalterable and indestructible by any other body but fire; whence it follows, that when it is not actually kindled and ignited, the most powerful agents, such as the acids, though ever so strong and concentrated, have not the least effect on it.

The case is otherwise when it is lighted, that is, when its phlogiston begins to separate from its earth; for then the pure acid of vitriol being joined therewith contracts an instantaneous union with its phlogiston, and evaporates in a volatile sulphureous spirit. If the vitriolic acid, instead of being applied quite pure, be first clogged with some basis, especially an alkaline one, it quits that basis, enters into a more intimate union with the phlogiston of the burning Coal, and so forms an actual sulphur, with which the alkali now unites and forms a hepar.

The pure acid of sea-salt hath not been observed to act in the least upon Charcoal, especially when it is not on fire. But when this acid is incorporated with an alkaline or metallic basis, and combined according to a peculiar process with burning Charcoal, it in like manner quits its basis, unites with the phlogiston, and therewith forms a Phosphorus, of which we have already taken notice.

Nor has the pure nitrous acid any effect on a charred Coal, even when ignited: and so far is it from being able to kindle a cold one, that when

poured on a live one, it extinguishes it like water. But when this acid is united with a basis, it quits it rapidly as soon as it touches a burning coal, and rushes violently into an union with the phlogiston thereof. From this union there probably arises, as we said before, a kind of sulphur or phosphorus, which is so inflammable as to be destroyed by the fire the very moment it is generated.

The acids of nitre and vitriol act upon Oils; but very differently, according to the quantity of phlegm they contain. If they be weakened with much water, they have no effect at all upon Oils; if they contain little water, or be dephlegmated to a certain degree, they dissolve them with heat, and with them form compounds of a thick consistence. Acids thus combined in a considerable proportion with Oils render them soluble in water.

## §. II. Of SOAP.

ALKALIS also have the same property. When an Oil is combined with an acid or an alkali in such a manner that the compound resulting from their union is soluble in water; such a compound may in general be called a *Soap*. Soap itself hath the property of rendering fat bodies in some measure soluble in water; on which account it is very useful for scouring or cleansing any thing greasy.

Oily and saline substances, combined together, observe the same general rules as all other combinations; that is, they mutually communicate the properties belonging to each: thus Oils, which naturally are not soluble in water, acquire by their union with saline matters the property of dissolving therein; and salts lose by their conjunction with Oils part of their natural tendency to incorporate with water; so that while they serve to constitute Soap, they do not, as before, attract the moisture of the air, &c. and in like manner, as they are not inflam-

inflammable, they considerably lessen the inflammability of the Oils combined with them.

Acid Soaps are decomposed by alkalis, as alkaline Soaps are by acids, according to the general rules of affinities.

The acids of nitre and vitriol, when highly concentrated, dissolve Oils with such violence as to heat them, make them black, burn them, and even set them on fire. How sea-salt affects Oils is not yet sufficiently ascertained.

All Oils have the property of dissolving sulphur; which is not at all surprising, seeing each of its component principles hath an affinity with Oil.

It is also a property common to all Oils to become more fluid, subtile, light, and limpid the oftener they are distilled. On the contrary, by being incorporated with saline substances they acquire a greater consistence, and sometimes form compounds that are almost solid.

## C H A P. XI.

### *Of the several Sorts of OILS.*

**O**ILS are distinguished by the substances from which they are drawn: and as Oils are extracted from minerals, from vegetables, and from animals, there are of course Mineral, Vegetable, and Animal Oils.

#### §. I. *Of MINERAL OILS.*

IN the bowels of the earth we find but one sort of Oil, called *Petroleum*: its smell is strong and not disagreeable, and its colour sometimes more some-  
times



times less yellow. There are certain mineral substances which yield by distillation a great deal of Oil very like Petroleum. This sort of substance is called a *Bitumen*, and is, indeed, nothing but an Oil rendered consistent and solid by being combined with an acid; as appears from hence, that by uniting Petroleum with the acid of vitriol we can produce an artificial Bitumen very like the native.

## §. II. Of VEGETABLE OILS.

VEGETABLE substances yield a very great quantity and variety of Oils; for there is not a plant, or part of a plant, that does not contain one or more sorts thereof, generally peculiar to itself, and different from all others.

By expression only, that is, by bruising and squeezing vegetable substances, particularly certain fruits and seeds, a sort of Oil is obtained which has scarce any smell or taste. Oils of this sort are very mild and unctuous; and, because in this respect they resemble animal fat more than the rest do, they are called *Fat Oils*.

These Oils, being exposed to the air for some time, sooner or later grow thick, acquire an acrid taste, and a strong disagreeable smell. Some of them congeal with the smallest degree of cold. This sort of Oil is well adapted to dissolve those preparations of Lead called Litharge and Minium, with which they form a thick tenacious substance, that is used for the basis of almost all plaisters. They also dissolve Lead in its metalline form; but not so easily as the sorts of calx abovementioned; probably because its body is not so much opened, nor its parts so divided.

By expression alone we also procure from certain vegetable substances another sort of Oil, which is thin, limpid, volatile, of a pungent taste, and retains the smell of the vegetable that yielded it; on  
which

which account it is called an *Essential Oil*. Of this there are several sorts, differing from one another like the Fat Oils, according to the subjects from which they are obtained.

We must observe that it is very difficult, or rather in most cases impossible, to force from the greatest part of vegetables, by expression only, all the essential Oil they contain. For this purpose therefore recourse must be had to fire: a gentle heat, not exceeding that of boiling water, will extract all the essential Oils of vegetables; and this is the most usual and most convenient way of procuring them.

The fat Oils cannot be obtained by the same method: these being much less volatile than the essential Oils require a much greater degree of heat to raise them; which nevertheless they cannot bear without being much spoiled and entirely changed in their nature, as shall presently be shewn. All Oils, therefore, which rise with the heat of boiling water, and such alone, should be called Essential Oils.

Essential Oils, in a longer or shorter time, according to the nature of each, lose their fragrant smell they had when newly distilled, and acquire another, which is strong, rancid, and much less agreeable: they also lose their tenuity, becoming thick and viscid; and in this state they greatly resemble those substances abounding in Oil which flow from certain trees, and which are called *Balsams* or *resins*, according as they are less or more consistent.

Balsams and Resins are not soluble in water. But there are other Oily compounds which likewise run from trees; and, though not unlike Resins, are however soluble in water. These are called *Gums*; and their property of dissolving in water arises from their containing more water and more salt than Resins have; or at least their saline parts are less clogged and more disengaged.

Balsams

Balsams and Resins distilled with the heat of boiling water yield great quantities of a limpid, subtile, odoriferous, and, in one word, essential Oil. In the still there remains a substance thicker and more consistent than the Balsam or Resin was before distillation. The same thing happens to essential Oils which by length of time have acquired a consistence and are grown resinous. If they be redistilled, they recover their former tenuity, leaving behind them a remainder thicker and more resinous than they themselves were. This second distillation is called the *Rectification* of an Oil.

It must be observed that an essential Oil, combined with an acid strong enough to dissolve it, immediately becomes as thick and resinous, in consequence of this union, as if it had been long exposed to the air: which proves the consistence an Oil acquires by long keeping to be owing to this, that its lightest and less acid parts being evaporated, the proportion of its acid to the remainder is so increased, that it produces therein the same change, as an additional acid mixed with the Oil would have wrought before the evaporation.

This also shews us that Balsams and Resins are only essential Oils combined with a great proportion of acid, and thereby thickened.

If vegetable substances, from which no more essential Oil can be drawn by the heat of boiling water, be exposed to a stronger heat, they yield an additional quantity of Oil; but it is thicker and heavier than the essential Oil. These Oils are black, and have a very disagreeable burnt smell, which hath made them be called *Fetid*, or *Empyreumatic* Oils. They are moreover very acrid.

It must be observed that, if a vegetable substance be exposed to a degree of heat greater than that of boiling water, before the fat or the essential Oil is extracted from it, an empyreumatic Oil  
only



only will then be obtained; because both the fat and essential Oils, when exposed to the force of fire, are thereby burnt, rendered acrid, acquire a smell of the fire, and, in a word, become truly empyreumatic. There is ground to think that an empyreumatic Oil is nothing else but an essential or fat Oil burnt and spoiled by the fire, and that no other Oil besides these two exists naturally in vegetables.

Empyreumatic Oils, distilled and rectified several times by a gentle heat, acquire by every distillation a greater degree of tenuity, lightness, and limpidity. By this means also they lose something of their disagreeable odour; so that they gradually come nearer and nearer to the nature of essential Oils: and if the rectifications be often enough repeated, ten or twelve times for instance, they become perfectly like those Oils; except that their smell will never be so agreeable, nor like that of the substances from which they were obtained.

Fat Oils may also be brought by the same means to resemble essential Oils: but neither essential nor empyreumatic Oils are capable of acquiring the properties of fat Oils.

### §. III. Of ANIMAL OILS.

DISTILLATION procures us considerable quantities of Oil from all the parts of animal bodies, and especially from their fat. This Oil at first is not very fluid, and is extremely fetid: but by many rectifications it gradually acquires a great degree of clearness and tenuity, and at the same time loses much of its disagreeable odour. Animal Oils, thus rendered thin and fluid by a great number of rectifications, have the reputation of being an excellent medicine, and a specific in the epilepsy.

## C H A P. XII.

*Of FERMENTATION in general.*

**B**Y Fermentation is meant an intestine motion, which, arising spontaneously among the insensible parts of a body, produces a new disposition and a different combination of those parts.

To excite a Fermentation in a mixt body it is necessary first, that there be in the composition of that mixt a certain proportion of watery, saline, oily, and earthy parts: but this proportion is not yet sufficiently ascertained. Secondly, it is requisite that the body to be fermented be placed in a certain degree of temperate heat: for much cold obstructs fermentation; and too much heat decomposes bodies. Lastly, the concurrence of the air is also necessary to fermentation.

All vegetable and animal substances are susceptible of Fermentation, because all of them contain in a due proportion the principles above specified. However, many of them want the proper quantity of water, and cannot ferment while they remain in such a state of dryness. But it is easy to supply that defect, and so render them very apt to ferment.

With respect to minerals properly so called, (that is, excluding such vegetable and animal substances as may have lain long buried in the earth,) they are not subject to any Fermentation; at least that our senses can perceive.

There are three sorts of Fermentation, distinguished from one another by their several productions. The first produces wines and spirituous liquors; for which reason it is called the *Vinous*  
or

or *Spirituos Fermentation*: the result of the second is an acid liquor; and therefore it is called the *Acetous Fermentation*: and the third generates an alkaline salt; which, however, differs from the alkaline salts hitherto treated of, in this respect chiefly that, instead of being fixed, it is extremely volatile: this last sort takes the name of the *Putrid* or *Putrefactive Fermentation*. We shall now consider these three sorts of Fermentation and their effects a little more particularly.

These three sorts of Fermentation may take place successively in the same subject; which proves them to be only three different degrees of fermentation, all proceeding from one and the same cause, rather than three distinct fermentations. These degrees of fermentation always follow the order in which we have here placed them.

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### C H A P. XIII.

#### *Of the SPIRITUOUS FERMENTATION.*

THE juices of almost all fruits, all saccharine vegetable matters, all farinaceous seeds and grains of every kind, being diluted with a sufficient quantity of water, are proper subjects of Spirituous Fermentation. If such liquors be exposed, in vessels slightly stopped, to a moderate degree of heat, they begin in some time to grow turbid; there arises insensibly a small commotion among their parts, attended with a hissing noise; this by little and little increases, till the grosser parts appear, like little seeds or grains, moving to and fro, agitated among themselves, and thrown up to the surface. At the same time some air bubbles rise,



and the liquor acquires a pungent, penetrating smell, occasioned by the very subtile vapours which exhale from it.

These vapours have never yet been collected, in order to examine their nature; and they are known only by their noxious effects. They are so actively pernicious, that if a man comes rashly into a close place, where large quantities of liquors are fermenting, he suddenly drops down and expires, as if he were knocked on the head.

When these several phenomena begin to go off, it is proper to stop the fermentation, if a very spirituous liquor be required: for if it be suffered to continue longer, the liquor will become acid, and from thence proceed to its last stage, that is, to putrefaction. This is done by stopping the containing vessels very close, and removing them into a cooler place. Then the impurities precipitate, and settling at the bottom leave the liquor clear and transparent: and now the palate discovers that the sweet saccharine taste it had before fermentation is changed to an agreeable pungency which is not acid.

Liquors thus fermented are in general called *Wines*: for though in common life that word properly signifies the fermented juice of grapes only, and particular names are given to the fermented juices of other vegetable substances; as that obtained from Apples is called *Cyder*; that made from malt is called *Beer*: yet in Chymistry it is of use to have one general term denoting every liquor that has undergone this first degree of fermentation.

By distillation we draw from Wine an inflammable liquor, of a yellowish white colour, light, and of a penetrating, pleasant smell. This liquor is the truly spirituous part of the wine, and the product of fermentation. That which comes off in the first distillation is commonly loaded with much  
phlegm

phlegm and some oily parts, from which it may be afterwards freed. In this state it goes by the name of *Brandy*; but when freed from these heterogeneous matters by repeated distillations, it becomes still clearer, lighter, more fragrant, and much more inflammable, and then is called *Spirit of Wine*, and *Rectified Spirit of Wine*, or an *Ardent Spirit*, if considerably purified. The properties which distinguish an Ardent Spirit from all other substances are its being inflammable; its burning and consuming entirely, without the least appearance of smoke or fuliginosity; its containing no particles reducible to a coal; and its being perfectly miscible with water. Ardent Spirits are lighter and more volatile than any of the principles of the mixts from which they were produced, and consequently more so than the phlegm, the acid, and the oil of which they themselves consist. This arises from a particular disposition of these principles, which are in a singular manner attenuated by fermentation, and thereby rendered more susceptible of expansion and rarefaction.

Ardent Spirits are supposed to be the natural solvents of oils and oily matters. But it is very remarkable that they dissolve essential oils only, without touching the fat of animals, or the fat oils obtained from vegetables by expression; yet when these oils have once undergone the action of fire, they become soluble in spirit of wine, and even acquire a new degree of solubility every time they are distilled. It is not so with essential oils, which can never be rendered more soluble in ardent spirits than they are at first; and are so far from acquiring a new degree of solubility every time they are distilled, that on the contrary they even in some measure lose that property by repeated rectifications.

I have taken some pains to find out the causes of these singular effects, and the result of my enquiries

quiries is published among the Memoirs of the Academy of Sciences for the year 1745. I therein consider ardent spirits as consisting of an oil, or at least a phlogiston, mixed with a portion of water, in which it is rendered soluble by means of an acid. This being laid down, I shew that the inability of spirit of wine to dissolve some oils must be imputed to its aqueous part, in which oils are not naturally soluble without the intervention of a salt: and that the power which this spirit exerts in dissolving other oils with ease, such as essential oils, must in all probability be owing to this, that in these oils it meets with the necessary saline medium, that is, with an acid, which numberless experiments shew they actually contain.

On the other hand, I there prove that the acid in essential oils is superabundant, and in some sort foreign to their nature, or that it is but slightly connected with them, and in part deserts them every time they are distilled; which renders them less soluble after every new rectification: whereas, on the contrary, the fat expressed oils in their natural state give not the least sign of acidity; but the action of fire upon them discovers an acid which was not perceivable before. Hence I conjecture that these oils contain no more acid than is just necessary to constitute them oils; that this acid is intimately blended with their other component parts; that it is so sheathed and entangled by these parts as to be incapable of exerting any of its properties; and that on this account these oils in their natural state are not soluble in spirit of wine: but that the disposition of their parts being gradually changed by the fire, and their acid, being by that means set more and more at liberty, at length recovers its properties, and particularly that of rendering the oily parts soluble in an aqueous menstruum: and hence it follows that the fat oils be-  
come



come so much the more soluble in spirit of wine the oftener they are exposed to the action of fire.

Spirit of wine doth not dissolve fixed alkalis; or at least it takes up but a very small quantity thereof; and hence ardent spirits may be freed from much of their phlegm by means of these salts thoroughly dried: for as they strongly imbibe moisture, and have even a greater affinity than ardent spirits with water, if a fixed alkali, well exsiccated, be mixed with spirit of wine that is not perfectly dephlegmated, the alkali immediately attracts its superfluous moisture, and is thereby resolved into a liquor, which on account of its gravity descends to the bottom of the vessel. The spirit of wine, which swims at top, is by this means as much dephlegmated, and as dry, as if it had been rectified by several distillations. As it takes up some alkaline particles in this operation, it is thereby qualified to dissolve oily matters with the greater facility. When rectified in this manner it is called *Alcoholized Spirit of Wine*.

Yet spirit of wine, even when rectified to an alcohol, is not capable of dissolving all oily matters. Those named Gums will by no means enter into any sort of union therewith; but it readily dissolves most of those which are known by the appellation of Resins. When it has dissolved a certain proportion of resinous particles it acquires a greater consistence, and forms what is called a *Spirit-Varnish*, or a *Drying Varnish*, because it soon dries. This Varnish is subject to be damaged by water. Many sorts thereof are prepared, differing from each other according to the different resins employed, or the proportions in which they are used. Most of these Varnishes are transparent and colourless.

Such bitumens or resins, as spirit of wine will not touch, are dissolved in oils, by means of fire, and then form another kind of Varnish, which water does

not hurt. These Varnishes are, usually coloured, and require much longer time to dry than the Spirit-Varnishes: they are called *Oil-Varnishes*.

Spirit of wine hath a much greater affinity with water than with oily matters: and therefore if a solution of any oil or resin in spirit of wine be mixed with water, the liquor immediately grows turbid, and acquires a whitish milky colour, owing entirely to the oily parts being separated from the spirituous menstruum by the accession of water, and too finely divided to appear in their natural form. But if the liquor stand some time quiet, several of these particles unite together, and gradually acquire a bulk sufficient to render them very perceptible to the eye.

Acids have an affinity with spirit of wine, and may be combined with it. By this union they lose most of their acidity, and on that account are said to be *Dulcified*. But as these combinations of acids, especially of the vitriolic acid, with spirit of wine, furnish some new productions of very singular properties, and as an examination thereof may throw much light on the nature of ardent spirits, it will not be amiss to take notice of them in this place, and consider each of them particularly.

One part of highly concentrated oil of vitriol being mixed with four parts of well dephlegmated spirit of wine, there arises immediately a considerable ebullition and effervescence, attended with great heat, and abundance of vapours, which smell pleasantly, but are hurtful to the lungs. At the same time is heard a hissing like that produced by a piece of red-hot iron plunged into water. Indeed it is proper to mix the liquors very gradually; for otherwise the vessels in which the operation is performed will be in great danger of breaking.

If the two liquors thus mixed be distilled with a very gentle heat, there rises first a spirit of wine of

a most

a most penetrating and grateful odour: when about half thereof is come over, what follows has a quicker and more sulphureous smell, and is also more loaded with phlegm. When the liquor begins to boil a little, there comes off a phlegm which smells very strong of sulphur, and grows gradually more acid. On this phlegm floats a small quantity of a very light and very limpid oil. In the still there remains a thick, blackish substance, somewhat like a resin or bitumen. From this substance may be separated a good deal of a vitriolic but sulphureous acid. When that is extracted, there remains a black mass like a charred coal, which being put into a crucible, and exposed to a violent heat, leaves a small portion of earth, very fixed, and even vitrifiable.

By rectifying the ardent spirit, which came over in distilling the abovementioned mixture, a very singular liquor is obtained, which differs essentially both from oils and from ardent spirits, though in certain respects it resembles them both. This liquor is known in Chymistry by the name of *Æther*, and its chief properties are as follow.

*Æther* is lighter, more volatile, and more inflammable, than the most highly rectified spirit of wine. It quickly flies off when exposed to the air, and suddenly catches fire when any flame approaches it. It burns like spirit of wine without the least smoke, and consumes entirely without leaving the smallest appearance of a coal or of ashes. It dissolves oils and oily matters with great ease and rapidity. These properties it has in common with an ardent spirit. But it resembles an oil in that it is not miscible with water; and this makes it essentially different from spirit of wine, the nature of which is to be miscible with all aqueous liquors.

Another very singular property of *Æther* is its great affinity with gold, exceeding even that of *aqua regis*. It does not indeed dissolve gold when in a



mass, and in its metalline form: but if a small quantity of *Æther* be added to a solution of gold in *aqua regis*, and the whole shaken together, the gold separates from the *aqua regis*, joins the *Æther*, and remains dissolved therein.

The reason of all the phenomena above-mentioned, resulting from the mixture of spirit of wine with oil of vitriol, is founded on the great affinity between this acid and water. For if the vitriolic acid be weak, and as it were over-dosed with watery parts, neither oil nor *Æther* can be obtained by means thereof: but when highly concentrated, it attracts the aqueous parts very powerfully; and therefore being mixed with spirit of wine, lays hold of most of the water contained in it, and even robs it of some portion of that which is essential to its nature, and necessary to constitute it spirit of wine: whence it comes to pass that a certain quantity of the oily particles in its composition being separated from the watery particles, and so brought nearer to each other, they unite and assume their natural form; and thus the oil that swims at top of the sulphureous phlegm is produced.

The vitriolic acid moreover thickens and even burns some of this oil; and hence comes the bituminous residuum left at the bottom of the still, which looks like the result of a vitriolic acid combined with common oil. Lastly, the vitriolic acid becomes sulphureous, as it always doth when united with oily matters, and also very aqueous, on account of the quantity of phlegm which it attracts from the spirit of wine.

*Æther* may be considered as a spirit of wine exceedingly dephlegmated, even to such a degree that its nature is thereby changed; so that the few aqueous particles left in it are not sufficient to dissolve the oily particles and keep them asunder; which therefore being now much nearer to one another

another than in common spirit of wine; the liquor hath lost its property of being miscible with water.

Spirit of nitre well dephlegmated, and combined with spirit of wine, presents likewise some very singular appearances.

First, in the very instant of its mixture with spirit of wine, it produces a greater and more violent effervescence than the vitriolic acid occasions.

Secondly, this mixture, without the help of distillation, and only by stopping the bottle in which the liquors are contained, affords a sort of Æther, produced probably by the vapours which ascend from, and swim at top of the mixture. This is a very singular liquor. Dr. Navier was the first that took notice of it, and gave a description thereof, which may be seen in the Memoirs of the Academy of Sciences.

Thirdly, some authors pretend that, by distilling the mixture under consideration, an oil is obtained greatly resembling that which, as we observed above, rises from spirit of wine combined with the vitriolic acid: others again deny this. For my part, I believe the thing depends on the different concentration of the spirit of nitre, as well as on the quality of the spirit of wine, which is sometimes more sometimes less oily.

Fourthly, the two liquors we are speaking of, being intimately mixed by distillation, form a liquor slightly acid, used in medicine, and known by the name of *Sweet* or *Dulcified Spirit of Nitre*: a very proper name, seeing the nitrous acid, by uniting with the spirit of wine, actually loses almost all its acidity and corrosive quality.

Fifthly and lastly, when the distillation is finished, there remains in the bottom of the vessel a thick, blackish substance, nearly resembling that which is found after distilling oil of vitriol and spirit of wine.

Spirit of Salt hath likewise been combined with spirit of wine; but it does not unite therewith so easily or so intimately as the two acids abovementioned. To mix them thoroughly, the spirit of salt must be highly concentrated, and sinoaking, and moreover the assistance of the still must be called in. Some authors pretend that from this mixture also a small quantity of oil may be obtained; which probably happens when the liquors have the qualities above specified. The marine acid likewise, by uniting with spirit of wine, loses most of its acidity; on which account it is in like manner called *Sweet* or *Dulcified Spirit of Salt*. A thick residuum is also found here after distillation.

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## C H A P. XV.

### *Of the* ACETOUS FERMENTATION.

BESIDES an ardent spirit, wine affords a great deal of water, oil, earth, and a sort of acid which shall be considered presently. When the spirituous part is separated from these other matters, they undergo no further change. But if all the constituent parts of wine remain combined together, then, after some time, shorter or longer as the degree of heat in which the wine stands is greater or less, the fermentation begins afresh, or rather arrives at its second stage. The liquor once more grows turbid, a new intestine motion arises, and after some days it is found changed into an acid; which, however, is very different from those hitherto treated of. The liquor then takes the name of *Vinegar*. The acetous fermentation differs from the spirituous, not only in its effect, but also in several of its concomitant circumstances.

Moderate



Moderate motion is of service to this, whereas it obstructs the spirituous; and it is attended with much more warmth than the spirituous. The vapours it produces are not noxious like those of fermenting wine. Lastly, Vinegar deposits no tartar, even when the wine employed in this operation is quite new, and hath not had time to discharge its tartar: instead of tartar Vinegar deposits a viscid matter which is very apt to putrify.

It must be observed that wine is not the only substance that is susceptible of the acetous fermentation: for several vegetable and even animal matters, which are not subject to the spirituous fermentation, turn sour before they putrify. But as vinous liquors possess in a very eminent degree the property of being susceptible of the acetous fermentation, and likewise of producing the strongest acids that can result from such fermentation, their acid shall be more particularly considered in this place.

#### §. I. Of VINEGAR.

IF wine, which has gone through this second stage of fermentation, be distilled, instead of an ardent spirit, only an acid liquor is obtained, which is called *Distilled Vinegar*.

This acid has the same properties as the mineral acids of which we have already treated; that is, it unites with alkaline salts, absorbent earths, and metallic substances, and therewith forms neutral saline combinations.

Its affinity with these substances observes the same order as that observed by the mineral acids with regard to the same substances; but in general it is weaker; that is, any mineral acid is capable of expelling the acid of Vinegar out of all matters with which it is united.

Vinegar hath likewise a greater affinity than sulphur with alkalis: whence it follows that it is capable

capable of decomposing that combination of sulphur with an alkali called Liver of Sulphur, and of precipitating the sulphur it contains.

The acid of Vinegar is always clogged with a certain proportion of oily parts, which greatly weaken it, and deprive it of much of its activity; and for this reason it is not near so strong as the mineral acids, which are not entangled with any oil. By distillation, indeed, it may be freed from this oil, and at the same time from the great quantity of water which in a manner suffocates it, and by that means it may be brought much nearer to the nature of the mineral acids: but this attempt hath not yet been prosecuted with the assiduity it deserves. Besides distillation, there is another way of freeing Vinegar from a good deal of its phlegm; and that is, by exposing it to a hard frost, which readily congeals the watery part into ice, while the acid retains its fluidity.

Vinegar, saturated with a fixed alkali, forms a neutral oily salt, of a dark colour, which is semi-volatile, melts with a very gentle heat, flames when thrown upon burning coals, and dissolves in spirit of wine, of which, however, it requires six parts to complete the solution. This solution being evaporated to dryness leaves a matter in the form of leaves lying on each other; on which account it hath obtained the name of *Terra Foliate*. The same foliated matter will be obtained, though the salt be not previously dissolved in spirit of wine; but not so readily. This salt is also called *Regenerated Tartar*. Under the head of Tartar we shall see the reason of these different appellations. Regenerated Tartar is also in some degree capable of crystallizing: for this purpose a solution thereof in water must be slowly evaporated to the consistence of a syrup, and then suffered to stand quiet in a cool place; by which means it will shoot into clusters

clusters of crystals, lying one upon another, not unlike the feathers on a quill.

With Vinegar and several absorbent earths, such as calcined pearls, coral, shells of fish, &c. are also formed neutral saline compounds, each of which takes the name of the particular earth employed in its composition.

Vinegar perfectly dissolves Lead, and converts it to a neutral metallic salt, which shoots into crystals, and has a sweet saccharine taste. This compound is called *Sugar of Lead*, or *Sal Saturni*.

If Lead be exposed to the bare vapour of Vinegar, it will be thereby corroded, calcined, and converted into a white matter much used in painting, and known by the name of *Ceruse*; or, when it is finer than ordinary, *White Lead*.

Vinegar corrodes Copper likewise, and converts it into a beautiful green rust, which also is used in painting, and distinguished by the name of *Verdegris*. However, Vinegar is not commonly employed to make Verdegris: for this purpose they use wine, or the rape of wine, from which fire extricates an acid analogous to Vinegar.

In treating of the several substances which constitute wine we mentioned an acid matter, but did not then enter into a particular examination thereof; because as that matter greatly resembles the acid of Vinegar, we thought it more proper to defer the consideration of its properties till we had treated of the acetous fermentation, and its effects.

## §. II. Of TARTAR.

THIS substance is a saline compound, consisting of earthy, oily, and especially acid parts. It is found in the form of crusts, adhering to the inner sides of vessels in which wines have stood for some time, particularly acid wines, such as those of Germany.

Tartar



Tartar derives its origin from the superabundant quantity of acid contained in the juice of the grape. This superfluous acid, being more than is requisite to constitute the ardent spirit, unites with some of the oil and earth contained in the fermented liquor, and forms a kind of salt; which for some time continues suspended in that liquor, but, when the wine stands undisturbed in a cool place, is deposited, as hath been said, on the sides of the cask.

Tartar in this state contains many earthy parts, which are superfluous, and foreign to its nature. From these it may be freed by boiling it repeatedly with a sort of earth found in the neighbourhood of Montpellier, as may be seen in the Memoirs of the Academy of Sciences.

When it is purified, there appears on the surface of the liquor a sort of white crystalline pellicle, which is skimmed off as it forms. This matter is called *Cream of Tartar*. The same liquor which produces this Cream, and in which the purified Tartar is dissolved, being set to cool yields a great number of white semi-transparent crystals, which are called *Crystals of Tartar*. The Cream and the Crystals of Tartar are therefore no other than purified Tartar, and differ from each other in their form only.

Though the Crystals of Tartar have every appearance of a neutral salt, yet they are far from being such; for they have all the properties of a true acid, which scarce differs from that of vinegar, except that it contains less water, and more earth and oil; to which it owes its solid form, as well as its property of not being soluble in water without much difficulty: for a very great quantity of water is requisite to keep the Crystals of Tartar in solution; and it must moreover be boiling hot; otherwise as soon as it cools most of the  
Tartar

Tartar dissolved in it separates from the liquor, and falls to the bottom in the form of a white powder.

Tartar is decomposed by calcination in the open fire. All its oily parts are consumed or dissipated in smoke, together with most of its acid. The other part of its acid, uniting-intimately with its earth, forms a very strong and very pure fixed alkali, called *Salt of Tartar*.

It will be shewn in its proper place that almost every vegetable matter, as well as Tartar, leaves a fixed alkali in its ashes: yet Tartar has these peculiar properties; first, it assumes an alkaline character even when burnt or calcined in close vessels, whereas other substances acquire it only by being burnt in the open air; secondly, the alkali of Tartar is stronger and more saline than almost any that is obtained from other matters.

This alkali, when thoroughly calcined, powerfully attracts the moisture of the air, and melts into an unctuous alkaline liquor, improperly called *Oil of Tartar per deliquium*. This is the alkali generally used in making the *Terra Foliata*, mentioned under the head of Vinegar: for which reason this combination is called *Terra Foliata Tartari*; a name suitable enough. But the same cannot be said of the other name, *Regenerated Tartar*, which is also given it. 'Tis true that on this occasion an oily acid is restored to the earth of the Tartar, analogous to that of which the fire had deprived it: but the compound thence resulting is a neutral salt which very readily dissolves in water; whereas Tartar is manifestly acid, and not soluble, or at least hardly soluble, in water.

Crystals of Tartar combined with alkali of Tartar produce a great effervescence while they are mixing, as all acids usually do; and if the combination be brought exactly up to the point of saturation,

saturation, a perfectly neutral salt is formed, which shoots into crystals, and easily dissolves in water; and this hath procured it the name of *Soluble Tartar*. It is also called the *Vegetable Salt*, as being obtained from vegetables only; and again, *Tartarised Tartar*, because it consists of the acid and the alkali of Tartar combined together.

Crystals of Tartar combined with alkalis procured from the ashes of maritime plants, such as Soda, which alkalis resemble the basis of sea-salt, form likewise a neutral salt, which crystallizes well, and dissolves easily in water. This salt is another sort of soluble Tartar. It is called *Saignette's Salt*, from the inventor's name.

Both the Vegetable Salt and Saignette's Salt are gently purgative soaps, and much used in Medicine.

Tartar likewise dissolves the absorbent earths, as lime, chalk, &c. and with them forms neutral salts which are soluble in water\*. It even attacks metallic bodies, and when combined with them, becomes soluble. A soluble Tartar for medical use is prepared with Crystals of Tartar and Iron: the metallic salt thereby produced hath the name of *Chalybeated Soluble Tartar*. This salt attracts the moisture of the air, and is one of those which do not crystallize.

Crystallized Tartar acts also upon several other metallic substances: for instance, it dissolves the Regulus, Liver, and Glass of Antimony, and thence acquires an emetic quality: it is then called *Stibiated or Emetic Tartar*. It likewise dissolves Lead, and therewith forms a salt which, in the figure of its crystals, resembles Tartarised Tartar.

It is very extraordinary that Tartar, which of itself is not soluble in water, should be soluble

\* See Mr. Duhamel's Essays on this subject in the Memoirs of the Academy of Sciences.



therein when become a neutral salt by uniting either with alkalis or with absorbent earths, or even with metals. With respect to alkalis, indeed, it may be urged that, having themselves a great affinity with water, they communicate to Tartar some of that facility with which they naturally unite therewith: but the same cannot be alledged concerning absorbent earths, and metallic substances, which water dissolves not at all, or at least with great difficulty, and in small quantity. This effect, therefore, must be attributed wholly to some change in the disposition of its parts which is to us unknown.

All the Soluble Tartars are easily decomposed by exposing them to a certain degree of heat. In distillation they yield the same principles which are obtained from Tartar; and what remains fixed in the fire, after they are thoroughly burnt, is a compound of the alkali which Tartar naturally produces, and of the alkaline or metallic substance with which it was converted into a neutral salt.

As Crystal of Tartar is the weakest of all acids, on account of the oily and earthy matters with which it is combined, Soluble Tartars are decomposed by all the acids; by any of which crystal of Tartar may be separated from the substance that serves it for a basis and renders it a neutral salt.

The other acids which are procured from vegetables, and even those which are obtainable from some animal substances, may all be referred to and compared with either Vinegar or Tartar, according to the quantities of oil or earth with which they are combined.

After all, these acids have not yet been thoroughly examined. There is great reason to think that they are no other than the mineral acids, which in passing through the bodies of vegetables, and even of animals, undergo a considerable change, especially by contracting an union with oily matters.

For,

For, as we said before in treating of Vinegar, by freeing them from their oil they are brought very near to the nature of mineral acids: and so likewise the mineral acids acquire many of the properties of vegetable acids by being combined with oils.

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## CHAP. XV.

### *Of the* PUTRID FERMENTATION, *or* PUTREFACTION.

EVERY body which hath gone through the two stages of fermentation above described, that is, the spirituous and the acetous fermentation, being left to itself in a due degree of warmth, which varies according to the subject, advances to the last stage of fermentation; that is, to putrefaction.

It is proper to observe, before we go any further, that the converse of this proposition is not true; that is, it is not necessary that a body should successively pass through the spirituous and the acetous fermentation, before it can arrive at the putrid; but that, as certain substances fall into the acetous without having gone through the spirituous fermentation, so others begin to putrify without having undergone either the spirituous or the acetous fermentation; of which last kind are, for instance, most animal substances. When therefore we represented these three sorts of fermentation as three different degrees or stages of one and the same fermentation, we supposed it to be excited in a body susceptible of fermentation in its full extent.

However, there is still room to think that every substance which is capable of fermenting always  
passes

passes necessarily through these three different stages; but that the substances most disposed thereto pass with such rapidity through the first, and even the second, that they arrive at the third before our senses can perceive the least signs of either of the two former. This opinion is not destitute of probability; yet it is not supported by proofs sufficiently strong and numerous to compel our assent.

When a body is in a putrefying state it is easy to discover, (as in the two sorts of fermentation already treated of) by the vapours which rise from it, by the opacity which invades it, if a pellucid liquor, and frequently even by a greater degree of heat than is found in the two other sorts of fermentation, that an intestine motion is begun among its constituent parts, which lasts till the whole be entirely putrefied.

The effect of this intestine motion is in this, as in the two other sorts of fermentation, to break the union, and change the disposition, of the particles constituting the body in which it is excited, and to produce a new combination. This is brought about by a mechanism to which we are strangers, and concerning which nothing beyond conjectures can be advanced: but these we neglect, resolving to keep wholly to facts, as the only things in Natural Philosophy that are positively certain.

If, then, we examine a substance that has undergone putrefaction, we shall soon perceive that it contains a principle which did not exist in it before. If this substance be distilled, there rises first, by means of a very gentle heat, a saline matter which is exceedingly volatile, and affects the organ of smelling briskly and disagreeably. Nor is the aid of distillation necessary to discover the presence of this product of putrefaction: it readily manifests itself in most substances where it exists, as



any one may soon be convinced by observing the different smell of fresh and of putrefied urine; for the latter not only affects the nose, but even makes the eyes smart, and irritates them so as to draw tears from them in abundance.

This saline principle which is the product of putrefaction, when separated from the other principles of the body which affords it, and collected by itself, appears either in the form of a liquor, or in that of a concrete salt, according to the different methods used to obtain it. In the former state it is called a *Volatile Urinous Spirit*; and in the latter a *Volatile Urinous Salt*. The qualification of urinous is given it, because, as was said, a great deal thereof is generated in putrefied urine, to which it communicates its smell. It goes also by the general name of a *Volatile Alkali*, whether in a concrete or in a liquid form. The enumeration of its properties will shew why it is called an Alkali.

Volatile Alkalis, from whatever substance obtained, are all alike, and have all the same properties; differing only according to their degrees of purity. The Volatile Alkali, as well as the Fixed, consists of a certain quantity of acid combined with and entangled by a portion of the earth of the mixt body from which it was obtained; and on that account it has many properties like those of a Fixed Alkali. But there is moreover in its composition a considerable quantity of fat or oily matter, of which there is none in a Fixed Alkali; and on this account again there is a great difference between them. Thus the Volatility of the Alkali produced by putrefaction, which is the principal difference between it and the other kind of Alkali whose nature it is to be Fixed, must be attributed to the portion of oil which it contains: for there is a certain method of volatilizing Fixed Alkalis by means of a fatty substance.

Volatile

Volatile Alkalis have a great affinity with acids, unite therewith rapidly and with ebullition, and form with them neutral salts, which shoot into crystals, but differ from one another according to the kind of acid employed in the combination.

The neutral salts which have a Volatile Alkali for their basis are in general called *Ammoniacal Salts*. That whose acid is the acid of sea-salt is called *Sal Ammoniac*. As this was the first known, it gave name to all the rest. Great quantities of this salt are made in Egypt, and thence brought to us. They sublime it from the foot of cow's dung, which is the fuel of that country, and contains sea-salt, together with a Volatile Alkali, or at least the materials proper for forming it; and consequently all the ingredients that enter into the composition of *Sal Ammoniac*. See the Memoirs of the Academy of Sciences.

The neutral salts formed by combining the acids of nitre and of vitriol with a Volatile Alkali are called, after their acids, *Nitrous Sal Ammoniac*, and *Vitriolic Sal Ammoniac*: the latter, from the name of its inventor, is also called Glauber's *Secrèt Sal Ammoniac*.

A Volatile Alkali, then, has the same property as a Fixed Alkali with regard to acids: yet they differ in this, that the affinity of the former with acids is weaker than that of the latter: and hence it follows that any *Sal Ammoniac* may be decomposed by a Fixed Alkali, which will lay hold of the Acid, and discharge the Volatile Alkali.

A Volatile Alkali will decompose any neutral salt which has not a Fixed Alkali for its basis; that is, all such as consist of an acid combined with an absorbent earth or a metallic substance. By joining with the acids in which they are dissolved, it disengages the earths or metallic substances, takes their

place, and in conjunction with their acids, forms Ammoniac Salts.

Hence it might be concluded that, of all substances, next to the Phlogiston and the Fixed Alkalis, Volatile Alkalis have the greatest affinity with acids in general. Yet there is some difficulty in this matter: for absorbent earths, and several metallic substances, are also capable of decomposing Ammoniacal Salts, discharging their Volatile Alkali, and forming new compounds by uniting with their acids. This might induce us to think that these substances have nearly the same affinity with acids.

But it is proper to observe, that a Volatile Alkali decomposes such neutral salts as have for their basis either an absorbent earth or a metallic substance, without the aid of fire; whereas absorbent earths or metallic substances will not decompose an Ammoniacal Salt, unless they be assisted by a certain degree of heat.

Now as all these matters are extremely fixed; at least in comparison with a Volatile Alkali, they have the advantage of being able to resist the force of fire, and so of acting in conjunction therewith; and fire greatly promotes the natural action of substances upon one another: whereas the Volatile Alkali in the Ammoniacal Salt, being unable to abide the force of fire, is compelled to desert its acid; and that so much the more quickly, as its affinity therewith is considerably weakened by the presence of an earthy or metallic substance, both of which have a great affinity with acids.

These considerations oblige us to conclude, that Volatile Alkalis have a somewhat greater affinity, than absorbent earths and metallic substances, with acids.

Ammoniacal Salts projected upon nitre in fusion make it detonate; and the Nitrous Sal Ammoniac  
detonates



detonates by itself, without the addition of any inflammable matter. This singular effect evidently demonstrates the existence of an oily matter in Volatile Alkalis; for it is certain that nitre will never deflagrate without the concurrence, and even the immediate contact, of some combustible matter.

This oily substance is often found combined with Volatile Alkalis in such a large proportion as to disguise it, in some measure, and render it exceeding foul. The salt may be freed from its superfluous oil by repeated sublimations; and particularly by subliming it from absorbent earths, which readily drink up oils. This is called *Rectification* of a Volatile Alkali. The salt, which before was of a yellowish or dirty colour, by being thus rectified becomes very white, and acquires an odour more pungent and less fetid than it had at first, that is, when obtained by one single distillation from a putrid substance.

It is proper to observe that the rectification of a Volatile Alkali must not be carried too far, or repeated too often; for by that means it may be entirely decomposed at length; and particularly if an absorbent earth, and especially chalk, be employed for that purpose, the salt may be converted into an oil, an earth, and water.

Volatile Alkalis act upon several metallic substances, and particularly on Copper; of which they make a most beautiful blue solution. On this property depends a pretty singular effect, which happens sometimes when we attempt, by means of a Volatile Alkali, to separate copper from any acid with which it is combined. Instead of seeing the liquor grow turbid, and the metal fall, both which generally happen when any Alkali whatever is mixed with a metallic solution, we are surprised to observe the solution of copper, upon adding a Volatile Alkali, retain its limpidity, and let fall no

precipitate; or at least if the liquor does grow turbid, it remains so but for a moment, and instantly recovers its transparency.

This is occasioned by adding such a quantity of Volatile Alkali as is more than sufficient fully to saturate the acid of the solution, and considerable enough to dissolve all the copper as fast as it is separated from the acid. On this occasion the liquor acquires a deeper blue than it had before; which arises from the property which Volatile Alkalis have of giving this metal, when combined with them, a fuller blue than any other solvent can: hence we have a touchstone to discover copper wherever it is; for let the quantity of this metal combined with other metals be ever so small, a Volatile Alkali never fails to discover it, by making it appear of a blue colour.

Though a Volatile Alkali be constantly the result of putrefaction, yet it must not therefore be imagined that none can be produced by any other means; on the contrary, most of those substances which contain the ingredients necessary to form it, yield no inconsiderable quantity thereof in distillation. Tartar, for example, which by being burnt in an open fire is converted, as was shewn, into a Fixed Alkali, yields a Volatile Alkali when it is decomposed in close vessels; that is, when it is distilled: because in this latter case the oily part is not dissipated or burnt, as it is by calcination in a naked fire, but has time to unite with some of the earth and acid of the mixt, in such a manner as to form a true Volatile Alkali.

To prove that on this occasion, as well as on all others, where unputrefied bodies yield a Volatile Alkali, this salt is the product of the fire, we need only observe, that in these distillations it never rises till after some part of the phlegm, of the acid, and even of the thick oil of the mixt, is come over; which

which never is the case when it is formed beforehand in the body which is the subject of the operation, as it is in those which have undergone putrefaction: for this salt, being much lighter and more volatile than those other substances, rises of course before them in distillation.

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## C H A P. XVI.

*A General View of* CHYMICAL  
DECOMPOSITION.

**T**HOUGH we have considered all the substances which enter into the composition of Vegetables, Animals, and Minerals, whether as primary or as secondary principles, it will not be improper to shew in what order we obtain these principles from the several mixts; and especially from Vegetables and Animals, because they are much more complicated than Minerals. This is called *Analysing* a compound.

The method most commonly taken to decompose bodies is by applying to them successive degrees of heat, from the gentlest to the most violent, in appropriated vessels, so contrived as to collect what exhales from them. By this means the principles are gradually separated from each other; the most volatile rise first, and the rest follow in order, as they come to be acted on by the proper degree of heat: and this is called *Distillation*.

But it being observed that fire, applied to the decomposition of bodies, most commonly alters their secondary principles very sensibly, by combining them in a different manner with each other, or even partly decomposing them, and reducing them



to their primitive principles; other means have been used to separate those principles without the help of fire.

With this view the mixts to be decomposed are forcibly compressed, in order to squeeze out of them all such parts of their substance as they will by this means part with; or else those mixts are for a long time triturated, either along with water, which carries off all their saline and saponaceous contents; or with solvents, such as ardent spirits, capable of taking up every thing in them that is of an oily or resinous nature.

We shall here give a succinct account of the effects of these different methods, as applied to the principal substances among Vegetables and Animals, and likewise to some Minerals.

#### §. I. *The ANALYSIS of VEGETABLE SUBSTANCES.*

A VAST many vegetable substances, such as kernels and seeds, yield by strong compression great quantities of mild, fat, unctuous Oils, which are not soluble in ardent spirits: these are what we called *Expressed Oils*. They are also sometimes called *Fat Oils*, on account of their unctuousness, in which they exceed all other sorts of Oil. As these Oils are obtained without the aid of fire, it is certain that they existed in the mixt just as we see them, and that they are not in the least altered; which could not have been the case had they been obtained by distillation; for that never produces any Oils but such as are acrid and soluble in spirit of wine.

Some vegetable matters, such as the rind of citrons, lemons, oranges, &c. also yield, only by being squeezed between the fingers, a great deal of Oil. This spirits out in fine small jets, which being received upon any polished surface, such as a looking-glass, run together and form a liquor that is a real Oil.

But

But it must be carefully noted that this sort of Oil, though obtained by expression only, is nevertheless very different from the Oils mentioned before, to which the title of *Expressed Oils* peculiarly belongs: for this is far lighter and thinner; moreover, it retains the perfect odour of the fruit which yields it, and is soluble in spirit of wine; in a word, it is a true essential Oil, but abounds so in the fruits which produce it, and is lodged therein in such a manner, occupying a vast number of little cells provided in the peel for its reception, that a very slight pressure discharges it; which is not the case with many other vegetables that contain an essential Oil.

Succulent and green plants yield by compression a great deal of liquor or juice, which consists of most of the phlegm, of the salts, and a small portion of the oil and earth of the plant. These juices, being set in a cool place for some time, deposite saline crystals, which are a combination of the acid of the plant with part of its oil and earth, wherein the acid is always predominant. These salts, as is evident from the description here given, bear a great resemblance to the tartar of wine treated of above. They are called *Essential Salts*; so that Tartar might likewise be called the *Essential Salt of Wine*.

Dried plants, and such as are of a ligneous, or acid nature, require to be long triturated with water, before they will yield their essential salts. Trituration with water is an excellent way to get out of them all their saline and saponaceous contents.

A vegetable matter that is very oily yields its essential salt with much difficulty, if at all; because the excessive quantity of oil entangles the salt so that it cannot extricate itself or shoot into crystals. Mr. Gerike, in his *Principles of Chymistry*, says, that if part of the oil of a plant be extracted by spirit of wine, its essential salt may be afterwards obtained

tained with more ease and in greater quantity. This must be a very good method for such plants as have an excessive proportion of essential oil; but will not succeed if the essential salt be hindered from crystallizing by a redundancy of fat oil, because fat oils are not soluble in spirit of wine.

Essential Salts are among those substances which cannot be extracted from mixts by distillation: for the first impression of fire decomposes them.

Though the acid which predominates in the Essential Salts of plants, be most commonly analogous to the vegetable acid, properly so called, that is, to the acid of vinegar and tartar, which is probably no other than the vitriolic acid disguised; yet it sometimes differs therefrom, and somewhat resembles the nitrous or the marine acid. This depends on the places where the plants grow which produce these salts: if they be maritime plants, their acid is akin to the acid of sea-salt; if on the contrary they grow upon walls, or in nitrous grounds, their acid is like that of nitre. Sometimes one and the same plant contains salts analogous to all the three mineral acids; which shews that the vegetable acids are no other than the mineral acids variously changed by circulating through plants.

Liquors containing the Essential Salts of plants being evaporated by a gentle heat to the consistence of honey, or even further, are called *Extracts*. Hence it is plain, that an Extract is nothing but the Essential Salt of a plant, combined with some particles of its oil and earth, that remained suspended in the liquor, and are now incorporated by evaporation.

Extracts of plants are also prepared by boiling them long in water, and then evaporating some part of it. But these Extracts are of inferior virtue; because the fire dissipates many of the oily and saline parts.

EMULSIONS.



## EMULSIONS.

Substances which abound much in Oil, being bruised and triturated with water for some time, afford a liquor of an opaque dead-white colour, like milk. This liquor consists of such juices as the water is capable of dissolving, together with a portion of the oil, which being naturally indissoluble in water, is only divided and dispersed in the liquor, the limpidity whereof is by that means destroyed. This sort of oily liquor, in which the oil is only divided, not dissolved, is called an *Emulsion*. The oily particles in Emulsions spontaneously separate from the water, when left at rest, and uniting into greater masses rise, on account of their lightness, to the surface of the liquor, which by that means recovers a degree of transparency.

If vegetables abounding in essential oils and resins be digested in spirit of wine, the menstruum takes up these oily matters, as being capable of dissolving them; and they may afterwards be easily separated from it by the affusion of water. The water, with which spirit of wine has a greater affinity than with oily matters, separates them by this means from their solvent, agreeably to the common laws of affinities.

Without the help of fire scarce any thing, besides the substances already mentioned, can be obtained from a plant: but by the means of distillation we are enabled to analyse them more completely. In prosecuting this method of extracting from a plant the several principles of which it consists, the following order is to be observed.

A plant being exposed to a very gentle heat, in a distilling vessel set in the *balneum marie*, yields a water which retains the perfect smell thereof. Some Chymists, and particularly the illustrious Boerhaave, have called this liquor the *Spiritus Rector*.

The

The nature of this odoriferous part of plants is not yet thoroughly known; because it is so very volatile that it is difficult to subject it to the experiments necessary for discovering all its properties.

If instead of distilling the plant in the *balneum marie*, it be distilled over a naked fire; with the precaution of putting a certain quantity of water into the distilling vessel along with it, to prevent its suffering a greater heat than that of boiling water, all the essential oil contained in that plant will rise together with that water, and with the same degree of heat.

On this occasion it must be observed that no essential oil can be obtained from a plant after the *Spiritus Rectior* hath been drawn off; which gives ground to think that the volatility of these oils is owing to that spirit.

The heat of boiling water is also sufficient to separate from vegetable matters the fat oils which they contain. That, however, is to be done by the way of decoction only, and not by distillation: because though these oils will swim on water, yet they will not rise in vapours without a greater degree of heat.

When the essential oil is come over, if the plant be exposed to a naked fire, without the addition of water, and the heat be increased a little, a phlegm will rise that gradually grows acid; after which, if the heat be increased as occasion requires, there will come over a thicker and heavier oil; from some a volatile alkali; and last of all, a very thick, black, empyreumatic oil.

When nothing more rises with the strongest degree of heat, there remains of the plant a mere coal only, called the *Caput Mortuum*, or *Terra Damnata*. This coal when burnt falls into ashes, which being lixiviated with water, gives a fixed alkali.

It

It is observable that in the distillation of plants which yield an acid and a volatile alkali, these two salts are often found quite distinct and separate in the same receiver; which seems very extraordinary, considering that they are naturally disposed to unite, and have a great affinity with one another. The reason of this phenomenon is that they are both combined with much oil, which embarrasses them so that they cannot unite to form a neutral salt, as they would not fail to do were it not for that impediment.

All vegetables, except such as yield a great deal of volatile alkali, being burnt in an open fire, and so as to flame, leave in their ashes a large quantity of an acrid, caustic, fixed alkali. But if care be taken to smother them, so as to prevent their flaming while they burn, by covering them with something that may continually beat down again what exhales, the salt obtained from their ashes will be much less acrid and caustic; the cause whereof is, that some part of the acid and oil of the plant being detained in the burning, and stopped from being dissipated by the fire, combines with its alkali. These salts crystallize, and being much milder than the common fixed alkalis, may be used in medicine, and taken internally. They are called *Tachenius's Salts*, because invented by that Chymist.

Marine plants yield a fixed alkali analogous to that of sea-salt. As for all other plants or vegetable substances, the fixed alkalis obtained from them, if rightly prepared and thoroughly calcined, are all perfectly alike, and of the very same nature.

The last observation I have to make on the production of fixed alkalis is, that if the plant you intend to work upon be steeped or boiled in water before you burn it, a much smaller quantity of salt will be obtained from it; nay, it will yield none at all, if repeated boilings have robbed it entirely of those



those saline particles which must necessarily concur with its earth to form a fixed Alkali.

§. II. *The ANALYSIS of ANIMAL SUBSTANCES.*

SUCCULENT animal substances, such as new-killed flesh, yield by expression a juice or liquid, which is no other than the phlegm, replete with all the principles of the animal body, except the earth, of which it contains but little. The hard or dry parts, such as the horns, bones, &c. yield a similar juice, by boiling them in water. These juices become thick, like a glue or jelly, when their watery parts are evaporated; and in this state they are true extracts of animal matters. These juices afford no crystals of essential salt, like those obtained from vegetables, and shew no sign either of an acid or an alkali.

Great part of the oil which is in the flesh of animals may be easily separated without the help of fire; for it lies in a manner by itself: it is commonly in a concrete form, and is called *Fat*. This oil somewhat resembles the fat oils of vegetables; for like them it is mild, unctuous, indissoluble in spirit of wine, and is subtilized and attenuated by the action of fire. But there is not in animals, as in vegetables, any light essential oil, which rises with the heat of boiling water; so that properly speaking, animals contain but one sort of oil.

Few animal substances yield a perceptible acid. Ants and bees are almost the only ones from which any can be obtained: and indeed the quantity they yield is very small, as the acid itself is extremely weak.

The reason thereof is, that as animals do not draw their nourishment immediately from the earth, but feed wholly either on vegetables or on the flesh of other animals, the mineral acids, which have already undergone a great change by the union con-

tracted between them and the oily matters of the vegetable kingdom, enter into a cloſer union and combination with theſe oily parts while they are paſſing through the organs and ſtrainers of animals; whereby their properties are deſtroyed, or at leaſt ſo impaired that they are no longer ſenſible.

Animal matters yield in diſtillation, firſt, a phlegm, and then, on increaſing the fire, a pretty clear oil, which gradually becomes thicker, blacker, more fetid, and empyreumatic. It is accompanied with a great deal of volatile alkali; and if the fire be raiſed and kept up till nothing more comes over, there will remain in the diſtilling veſſel a coal like that of vegetables; except that when it is reduced to aſhes, no fixed alkali, or at leaſt very little, can be obtained from them, as from the aſhes of vegetables. This ariſes from hence that, as we ſaid before, the ſaline principle in animals being more intimately united with the oil than it is in plants, and being conſequently more attenuated and ſubtilized, is too volatile to enter into the combination of a fixed alkali; on the contrary it is more diſpoſed to join in forming a volatile alkali, which on this occaſion does not riſe till after the oil, and therefore muſt certainly be the production of the fire. It muſt be obſerved, that all we have hitherto ſaid concerning the analyſis of bodies muſt be underſtood of ſuch matters only as have not undergone any ſort of Fermentation.

The chyle and the milk of animals which feed on plants ſtill retain ſome likenefs to vegetables; becauſe the principles of which theſe liquors are compoſed have not gone through all the changes which they muſt ſuffer before they enter into the animal combination.

Urine and ſweat are excrementitious aqueous liquors, loaded chiefly with the ſaline particles which are of no ſervice towards the nourishment of the

the animal, but pass through its strainers without receiving any alteration; such as the neutral salts which have a fixed alkali for their basis, and particularly the sea-salt, which happens to be in the food of animals, whether it exist therein naturally as it does in some plants, or whether the animals eat it to please their palates.

The saliva, the pancreatic juice, and especially the bile, are saponaceous liquors, that is, they consist of saline and oily particles combined together: so that being themselves dissolved in an aqueous liquor, they are capable of dissolving likewise the oily parts, and of rendering them miscible with water.

Lastly, the blood being the receptacle of all these liquors partakes of the nature of each, more or less in proportion to the quantity thereof which it contains.

### §. III. *The ANALYSIS of MINERAL SUBSTANCES.*

MINERALS differ greatly from vegetables, and from animals; they are not near so complex as those organized bodies, and their principles are much more simple; whence it follows that these principles are much more closely connected, and that they cannot be separated without the help of fire; which not having on their parts the same action and the same power as on organized bodies, hath not the same ill effect on them; I mean the effect of changing their principles, or even destroying them entirely.

I do not here speak of pure, vitrifiable, or refractory earths; of mere metals and semi-metals; of pure acids; or even of their simplest combinations, such as sulphur, vitriol, allum, sea-salt: of all these we have said enough.

We are now to treat of bodies that are more complex, and therefore more susceptible of decomposition.



composition. These bodies are compound masses, or combinations of those above-mentioned; that is, metallic substances as they are found in the bowels of the earth, united with several sorts of sand, stones, earths, semi-metals, sulphur, &c. When the metallic matter is combined with other matters, in such a proportion to the rest that it may be separated from them with advantage and profit, these compounds are called *Ores*: when the case is otherwise, they are called *Pyrites*, and *Marcasites*; especially if sulphur or arsenic be predominant therein, which often happens.

In order to analyse an ore, and get out of it the metal it contains, the first step is to free it from a great deal of earth and stones, which commonly adhere to it very slightly and superficially. This is effected by pounding the ore, and then washing it in water; to the bottom of which the metalline parts presently sink, as being the heaviest, while the small particles of earth and stone remain suspended some time longer.

Thus the metallic part is left combin'd with such matters only as are most intimately complicated with it. These substances are most commonly sulphur and arsenic. Now as they are much more volatile than other mineral matters, they may be dissipated in vapours, or the sulphur may be consumed, by exposing the ore which contains them to a proper degree of heat. If the sulphur and arsenic be desired by themselves, the fumes thereof may be caught and collected in proper vessels and places. This operation is called *Roasting* an Ore.

The metal thus depurated is now fit to be exposed to a greater force of fire, capable of melting it.

On this occasion the semi-metals and the imperfect metals require the addition of some matter abounding in phlogiston, particularly charcoal-dust; because these metallic substances lose their

phlogiston by the action of the fire, or of the fluxes joined with them, and therefore without this precaution would never acquire either the splendour or the ductility of a metal. By this means the metallic substance is more accurately separated from the earthy and stony parts, of which some portion always remains combined therewith till it is brought to fusion. For, as we observed before, a metallic glass or calx only will contract an union with such matters; a metal possessed of its phlogiston and metalline form being utterly incapable thereof.

We took notice of the cause of this separation above, where we shewed that a metal possessed of its phlogiston and metalline form will not remain intimately united with any calcined or vitrified matter, not even with its own calx or glass.

The metal therefore on this occasion gathers into a mass, and lies at the bottom of the vessel, as being most ponderous; while the heterogeneous matters float upon it in the form of glass, or a semi-vitrification. These floating matters take the name of *Scoriæ*, and the metalline substance at bottom is called the *Regulus*.

It frequently happens that the metalline regulus thus precipitated is itself a compound of several metals mixed together, which are afterwards to be separated. We cannot at present enter into a detail of the operations necessary for that purpose: they will appear in our *Treatise of Practical Chymistry*: but the principles on which they are founded may be deduced from what we have said above, concerning the properties of the several metals and of acids.

It is proper to observe, before we quit this subject, that the rules here laid down for analysing ores are not absolutely general: for example, it is often advisable to roast the ore before you wash it; for by that means some ores are opened, attenuated, and made very friable, which would cost much  
trouble

trouble and expence, on account of their excessive hardness, if you should attempt to pound them without a previous torrefaction.

It is also frequently necessary to separate the ore from part only of its stone; sometimes to leave the whole; and sometimes to add more to it, before you smelt it. This depends on the quality of the stone, which always helps to promote fusion when it is in its own nature fusible and vitrifiable. It is then called the *Fluor* of the ore: but of this we must say as we did of the preceding article; it is sufficient for our present purpose to lay down the fundamental principles on which the reason of every process is built; the description of the operations themselves being reserved for our second Part.

We shall now give a succinct account of the principal ores and mineral bodies, contenting ourselves with just pointing out the particulars of which they severally consist.

### *Of the PYRITES.*

#### *The yellow Pyrites.*

THE yellow Pyrites is a mineral consisting of sulphur, iron, an unmetallic earth, and frequently a little copper: the sulphur, which is the only one of these principles that is volatile, may be separated from the rest by sublimation: it usually makes a fourth, and sometimes a third, of the whole weight of these Pyrites. The other principles are separated from one another by fusion and reduction with the phlogiston, which; by metallizing the ferruginous and cupreous earths, parts them from the unmetallic earth: for this earth vitrifies, and cannot afterwards continue united with metallic matters possessed of their metalline form, as hath been said before.



There is yet another way of decomposing the yellow Pyrites, which is to let it lie till it effloresces, or begins to shoot into flowers; which is nothing but a sort of slow accension of the sulphur it contains. The sulphur being by this means decomposed, its acid unites with the ferruginous and cupreous parts of the Pyrites, and therewith forms green and blue vitriols; which may be extracted by steeping in water the Pyrites which has effloresced or been burnt, and then evaporating the lixivium to a pellicle; for by this means the vitriol will shoot into crystals.

Sometimes the Pyrites contains also an earth of the same nature with that of alum: a Pyrites of this sort, after flowering, yields alum as well as vitriol.

#### *The White Pyrites.*

THE white Pyrites contains much arsenic, a ferruginous earth, and an unmetallic earth. The arsenic being a volatile principle may be separated by sublimation or distillation from the rest, which are fixed: and these again may be disjoined from each other by fusion and reduction, as was said in relation to the yellow Pyrites.

#### *The Copper Pyrites.*

THE Copper Pyrites contains sulphur, copper, and an unmetallic earth. A great deal thereof likewise holds arsenic, and its colour approaches more or less to Orange, yellow, or white, according to the quantity of arsenic in it. It may be decomposed by the same means as the yellow and white Pyrites.

## OF ORES.

*Of Gold Ores.*

GOLD being constantly found in its metalline form, and never combined with sulphur and arsenic, its matrices are not, properly speaking, ores; because the metal contained in them is not mineralized. The gold is only lodged between particles of stone, earth, or sand, from which it is easily separated by lotion, and by amalgamation with quick-silver. The gold thus found is seldom pure, but is frequently alloyed with more or less silver, from which it is to be separated by quartation.

It is also very common to find gold in most ores of other metals or semi-metals, and even in the Pyrites; but the quantity contained therein is generally so small, that it would not pay the cost of extracting it. However, if any should incline to attempt it, merely out of curiosity, it would be necessary to begin with treating these ores in the manner proper for separating their metalline part; then to cupel the metalline regulus so obtained; and lastly to refine it by quartation.

*Of Silver Ores.*

IT is no rare thing to find silver, as well as gold, in its metalline form, only lodged in sundry earths and stony matters, from which it may be separated in the same manner as gold. But the greatest quantities of this metal are usually dug out of the bowels of the earth in a truly mineral state; that is, combined with different substances, and particularly with sulphur and arsenic.

Several silver ores are distinguished by peculiar characteristics, and are accordingly denoted by particular names. That which is called the *Vit-*

*treous Silver Ore*, is scarce any thing else but a combination of silver and sulphur. Another is known by the name of the *Horny Silver Ore*, because when in thin plates it is semi-transparent: in this ore the silver is mineralized by sulphur and a little arsenic. The *Red Silver Ore* is of the colour which its name imports, sometimes more, sometimes less vivid; and is chiefly composed of silver, arsenic, and sulphur: it also contains a little iron.

These three ores are very rich in silver: the first contains nearly three-fourths of its weight, and the others about two-thirds of theirs.

There is a fourth, called the *White Silver Ore*, which though it be heavier, is not so rich in silver, because it contains much copper. Many other minerals contain silver, yet are not, properly speaking, silver ores; because a much greater quantity of other metals than of silver is found in them.

When a silver ore is to be decomposed, in order to have the silver pure, or when silver is to be extracted out of any ore that contains it, the first thing to be done is to roast the ore, in order to clear it of the volatile minerals: and as silver cannot be had pure without the operation of the cupel, which requires more or less lead to be joined with it, it is usual to mix with the torrified silver ore a quantity of lead, proportioned to that of the heterogeneous matters combined with the silver, and to melt the whole together. Part of the added lead vitrifies during the fusion, and at the same time converts some of the heterogeneous matters also into glass, with which it forms a scoria that rises to the surface of the matter. The other part of the lead, with which the silver is mixed, falls to the bottom in the form of a regulus, which must be cupelled in order to have the silver pure.



*Of Copper Ores.*

COPPER is much seldomer found in a metalline form, than gold or silver: it is commonly in a mineral state: it is mineralized by sulphur and arsenic: almost all its ores contain also more or less iron; sometimes a little silver or even gold, together with unmetallic earths and stones, as all ores do.

Most copper ores are of a beautiful green or blue, or else in shades blended of these two colours. The minerals called *mountain green*, and *mountain blue*, are true copper ores; not in the form of hard stones, like other ores, but crumbly and friable like earth.

Nevertheless there are several copper ores of different colours, as ash-coloured, whitish, and shaded with yellow or orange; which colours arise from the different proportions of arsenic, sulphur, and iron, which these ores contain.

In order to decompose a copper ore, and to extract the copper it contains, it is first of all to be freed from as many of its earthy, stony, sulphureous and arsenical parts, as is possible, by roasting and washing; then what remains is to be mixed with a flux compounded of a fixed alkali and some inflammable matter; a little sea-salt is to be put over all, and the whole melted by a strong fire. The salts facilitate the fusion and scorification of the unmetallic matters, and therewith form a slag, which being the lightest rises to the surface. The metalline matters are collected below in the form of a shining regulus of copper; which, however, is not usually fine copper, but requires to be purified in the manner to be shewn in our second part.

In order to separate the copper from the unmetallic matters, it is absolutely necessary to melt its ore along with inflammable substances abounding in

phlogiston. For, as this metal is not possessed of its metalline form while it is in a mineral state, as it is destitute of the true quantity of phlogiston, and, though it were not, would lose it by the action of the fire, it would come to pass that if its ore were melted without the addition of any inflammable matter, the cupreous earth or calx would be scorified and confounded with the unmetallic matters; and as all metallic matters, except gold and silver, are subject to this inconvenience as well as copper, the addition of an inflammable substance, in fluxing all ores that contain them, is a general rule that ought constantly to be observed.

### *Of Iron Ores.*

IRON is seldom found pure and malleable in the earth; yet it is much seldomer found in the mineral state, properly so called, than any of the other metals: for most iron ores are scarce any thing more than a ferruginous earth mixed in different proportions with unmetallic earths and stones. Some of them, however, contain also volatile minerals, such as sulphur and arsenic; and therefore it is necessary to roast the iron ores, like all others, before you attempt to extract the metal out of them. That being done, they are to be smelted with a flux consisting of fusible and inflammable matters, as the general rule directs.

Iron is the commonest of all metals; nay, it is so universally diffused through the earth, that it is difficult to find any earth, stone, or sand, that does not contain some of it; and therefore none of these are usually considered and treated as iron ores, except such as contain a great deal of that metal, and melt easily. The hematites, emery, yellow pyrites, calamine, all contain a pretty considerable quantity of iron; but nobody attempts to extract it from them, because they are very hard to melt.

Ferru-

Ferruginous earth being naturally of an orange colour, a stone or earth may be judged to contain iron, if either naturally, or after roasting, it appears to have one shade of yellow or red.

The singular property which iron has of being attracted by the magnet, and of being the only body, exclusive of all others, that is so, likewise affords us an easy method of discovering the presence of this metal among other matters, where it often exists in such a small quantity that it could not otherwise be found out. For this purpose the body in which iron is suspected to lurk, must be pulverised and torrefied with some inflammable matter; and then the powder thus roasted being touched with a magnet, or an animated bar, if it contains any particles of iron they will infallibly adhere to the magnet or bar.

#### *Of Tin Ores.*

TIN is never found in the earth pure and malleable, but always in a mineral state, and always mineralized by arsenic. Tin ores are not sulphureous; whence it comes that though tin be the lightest of all metals, its ores are nevertheless heavier than those of other metals, as arsenic greatly exceeds sulphur in gravity. Some tin ores contain also a little iron. The ores of tin are to be washed, roasted, and smelted with a reducing flux, according to the general rules.

#### *Of Lead Ores.*

LEAD, like tin, is never found but in a mineral state. It is most commonly mineralized by sulphur; yet there are some lead ores which also contain arsenic.

Lead ores, as well as others, must be roasted and smelted with a reducing flux: however, as it is difficult



ficult to free them from all their sulphur by torrefaction only, the reducing flux employed in their fusion may be made up with a quantity of iron filings, which being incapable of any union with lead, and having a much greater affinity than that metal with sulphur, will on this occasion be of great service by interposing between them.

### *Of Quick-silver Ores.*

RUNNING Mercury is sometimes found in certain earths, or grey, friable stones; but most commonly in a mineral state. It is always mineralized by sulphur, and by sulphur alone: so that cinabar is the only ore of quick-silver that we know of: and a very rich one it is, seeing it contains six or seven times as much mercury as sulphur.

Roasting can be of no use towards decomposing the ore of mercury, and separating its sulphur; because mercury being itself very volatile would be carried off by the fire together with the sulphur. In order therefore to part the two substances of which cinabar consists, recourse must necessarily be had to some third body, which will unite with one of them, and by that means separate it from the other. Now all the metals, except Gold, having a greater affinity than mercury with sulphur, such a body is easily found: any metal but Gold may be employed with success in this decomposition; but as iron hath a greater affinity with sulphur than any of the rest, and is moreover the only one that cannot unite with mercury, it must on account of these two qualities be preferred to all the rest.

Fixed alkalis are also well qualified to absorb the sulphur of cinabar. Cinabar must be decomposed in close vessels, and by the way of distillation; otherwise the mercury, as soon as it separates  
from

from the sulphur, will be dissipated in vapours and entirely lost.

In this operation it is needless to add either flux or phlogiston; because the cinabar is decomposed without melting, and the mercury, though in a mineral state, contains, like gold and silver, all the phlogiston requisite to secure its metalline properties.

*Of the Ores of Regulus of Antimony.*

REGULUS of Antimony is always found in a mineral state: it is mineralized by sulphur; but sometimes, though rarely, it is also combined with a little arsenic.

When the ore of regulus of antimony is to be decomposed, the first thing to be done is to expose it to a degree of heat too weak to melt its earthy and stony parts, but strong enough to fuse its reguline, together with its sulphureous parts, which by this means are separated from the earth, and united into one mass, known by the name of Antimony.

It is plain that this first operation, which is founded on the great fusibility of antimony, produces, with regard to the ore of regulus of antimony, the same effect that washing hath on other ores: so that after this first fusion nothing more is requisite to the obtaining of a pure regulus of antimony, but to separate it from its sulphur by roasting, and to melt it with some matter abounding in phlogiston, in the same manner as other metallic matters are treated. The term *Calcination* is generally used to express this torrefaction of antimony, by means whereof the metallic earth of the regulus of antimony is separated from its sulphur.

As regulus of antimony hath, like mercury, much less affinity with sulphur than the other metals have, it follows that antimony may be decomposed by the same means as cinabar; but the regulus

lus so obtained is adulterated with a portion of the additament made use of, which combines therewith.

There is still another process employed for obtaining the regulus of antimony: it consists, as was mentioned in its place, in detonating the mineral with a mixture of nitre and tartar, applied in such a proportion that, after the detonation has consumed the sulphur, there may remain so much inflammable matter as will be sufficient to furnish the metalline earth of the antimony with the phlogiston necessary to preserve its metallic properties. But by this method less regulus is produced, than by calcining, or torrefying, and reducing as usual.

#### *Of the Ores of Bismuth.*

THE ore of Bismuth consists of the semi-metal mineralized by arsenic, and of an unmetallic earth. It is very easy to decompose this ore, and to extract the bismuth it contains: for this purpose it need only be exposed to a moderate heat, whereby the arsenic will be dissipated in vapours, and the bismuth melted, which will then separate from the unmetallic earth. This earth, at least, in several ores of bismuth, possesses the property of tinging all vitrifiable matters, with which it is melted, of a beautiful blue colour.

To decompose the ore of bismuth no flux or inflammable matter is used; because this semi-metal is possessed, even in its mineral state, of all the phlogiston requisite to maintain its metalline properties; and its great fusibility makes it unnecessary to melt the unmetallic earth contained in its ore.

#### *Of the Ores of Zinc.*

ZINC is not generally obtained from a particular ore of its own; but sublimes during the fusion of a mineral, or rather a confused mass of minerals, that



that contains this semi-metal together with iron, copper, lead, sulphur, arsenic, and, like all other ores, an unmetallic earth.

Nevertheless there is a substance which may be considered as the proper ore of zinc, because it contains a pretty large quantity of that semi-metal, a little iron, and an unmetallic earth. It is called *Calamine*, or *Lapis Calaminaris*: but hitherto the art of procuring zinc directly from this mineral hath no where been practised. Calamine is commonly employed only to convert copper into brass, or a yellow metal, by cementing it therewith. Indeed till lately no easy or practicable method of obtaining pure zinc from calamine was publicly known; for that semi-metal being volatile and very inflammable, its ore cannot be fused like others. Mr. Margraaf was the first who, by mixing powdered charcoal with calamine in close vessels, obtained a perfect zinc from it, by the means of distillation or sublimation, as shall be shewn in our Practical Chymistry.

### *Of Arsenical Minerals.*

ARSENIC, as well as sulphur, is naturally combined with almost all ores, or minerals containing metallic substances. As it is very volatile, while the matters with which it is united are fixed, at least in comparison therewith, it is easily separated by sublimation.

The minerals that contain most arsenic are the white pyrites, orpiment, and cobalt. We have already considered the white pyrites: as to Orpiment, it consists of sulphur and arsenic. Both these substances being very volatile, it is difficult to separate them by sublimation: yet, with proper management, and a due regulation of the fire, this separation may be effected; because sulphur sublimes a little more easily than arsenic. But it is more convenient

nient, as well as more expeditious, to make use of some additament that hath a greater affinity with one of those substances than with the other. Fixed alkalis and mercury, both of which have more affinity with sulphur than with arsenic, may be very properly employed on this occasion.

Cobalt is a mineral composed of arsenic, an unmetallic earth, and frequently bismuth: and as none of these are very volatile, except the arsenic, this may be easily separated from the rest by sublimation. The unmetallic earth which remains has, like that of the ore of bismuth, the property of giving a blue colour to any vitrifiable matters melted with it; whence it is conjectured that cobalt and the ore of bismuth have a great resemblance, or are often blended with each other. Nevertheless Mr. Brant, an ingenious Swedish Chymist, insists that they are very different: he pretends that the metallic substance contained in the true cobalt is a semi-metal of a peculiar nature, which hath been erroneously confounded with bismuth: and indeed he proves by a great number of curious experiments, related in the Memoirs of the Academy of Upsal, that these two metallic substances have properties that are essentially different: to that which is obtained from cobalt, he gives the name of *Regulus of Cobalt*.

Besides the minerals already recited, there is found in the bowels of the earth another species of compound body, of which we have already taken notice; but which is supposed, with some degree of probability, to belong as much to the vegetable as to the mineral kingdom: I mean the *Bitumens*; which the best observations oblige us to consider as vegetable oils, that by lying long in the earth have contracted an union with the mineral acids, and by that means acquired the thickness, consistence, and other properties observable in them.

By distillation they yield an oil, and an acid not unlike a mineral acid. Mr. Bourdelin has even demonstrated, by a very artful and ingenious process, that amber contains a manifest acid of sea-salt. See the Memoirs of the Royal Academy of Sciences.

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## C H A P. XVII.

*Explanation of the Table of Affinities.*

IT hath been shewn in the course of this work that the causes of almost all the phenomena, which Chymistry exhibits, are deducible from the mutual affinities of different substances, especially the simplest. We have already explained, (Chap. II.) what is meant by affinities, and have laid down the principal laws to which the relations of different bodies are subject. The late Mr. Geoffroy, one of the best Chymists we have had, being convinced of the advantages which all who cultivate Chymistry would receive from having constantly before their eyes a state of the best ascertained relations between the chief agents in Chymistry, was the first who undertook to reduce them into order, and unite them all in one point of view, by means of a table. We are of opinion, with that great man, that this Table will be of considerable use to such as are beginning to study Chymistry, in helping them to form a just idea of the relations which different substances have with one another; and that the practical Chymist will thereby be enabled to account for what passes in several of his operations, otherwise difficult to be understood, as well as to judge what may be expected to result from mixtures of different compounds. These reasons have



have induced us to insert it at the end of this Elementary Treatise, and to give a short explanation of it here; especially as it will serve, at the same time, for a recapitulation of the whole work, in which the several axioms of this Table are dispersed.

You have it here just as it was drawn up by Mr. Geoffroy, without any addition or alteration. I own, however, that it might be improved both ways: for since the death of that great Chymist many experiments have been made, some of which have discovered new affinities, and others have raised exceptions to some of those laid down by him. But several reasons dissuade me from publishing a new Table of Affinities, containing all the emendations and innovations that might be made in the old one.

The first is, that many of the affinities lately discovered are not yet sufficiently verified, but, on the contrary, subject to be contested: in short, they are perhaps liable to more considerable objections and exceptions than the other.

The second is, that as Mr. Geoffroy's Table contains all the fundamental affinities, it is more suitable to an Elementary Treatise than a much fuller one would be; seeing this would necessarily suppose the knowledge of many things not treated of by us, and of which it was not proper to say any thing in such a book as this.

However, as it is essential to our purpose that we lead none into error, we shall take care in explaining the affinities delivered by Mr. Geoffroy, to mention the principal objections and exceptions to which they are liable: we shall moreover add a very few new ones, confining ourselves to such only as are elementary and well ascertained.

The upper line of Mr. Geoffroy's Table, comprehends several substances used in Chymistry. Under each of those substances are ranged in distinct

tinct columns several matters compared with them; in the order of their relation to that first substance; so as that which is the nearest to it is that which hath the greatest affinity with it, or that which none of the substances standing below it can separate therefrom; but which, on the contrary, separates them all when they are combined with it, and expels them in order to join itself therewith. The same is to be understood of that which occupies the second place of affinity; that is, it has the same property with regard to all below it, yielding only to that which is above it: and so of all the rest.

At the top of the first column stands the character which denotes an Acid in general. Immediately under this stands the mark of a Fixed Alkali, being placed there as the substance which has the greatest affinity with an Acid. After the Fixed Alkali appears the Volatile Alkali, whose affinity with Acids yields only to the Fixed Alkali. Next come the Absorbent Earths; and last of all Metallic Substances. Hence it follows that when a Fixed Alkali is united with an Acid it cannot be separated therefrom by any other substance; that a Volatile Alkali united with an Acid cannot be separated from it by any thing but a Fixed Alkali; that an Absorbent Earth combined with an Acid may be separated from it either by a Fixed or by a Volatile Alkali; and lastly, that any Metallic Substance combined with an Acid may be separated from it by a Fixed Alkali, a Volatile Alkali, or an Absorbent Earth.

There are many important remarks to be made on this first column. First, it is making the rule too general to say that any Acid whatever has a greater affinity with a Fixed Alkali, than with any other substance. And indeed Mr. Geoffroy himself hath made an objection with respect to the Vitriolic Acid: for in the fourth column, at the head of which stands that Acid, we find the sign of the

Phlogiston placed above that of the Fixed Alkali, as having a greater affinity than the Fixed Alkali with the Vitriolic Acid. This is founded on the famous experiment, wherein Vitriolated Tartar and Glauber's Salt are decomposed by means of the Phlogiston, which separates the Fixed Alkalis of these Neutral Salts, and uniting with the Vitriolic Acid contained in them forms therewith a Sulphur.

Secondly, Nitre deflagrates, and is decomposed, by the contact of any inflammable matter whatever that is actually ignited; and the operation which produces Phosphorus is no other than a decomposition of sea-salt, whose Acid quits its Alkaline basis to join with the Phlogiston: now these facts furnish very strong reasons for believing that both these Acids, as well as the Vitriolic, have a stronger affinity with the Phlogiston than with a Fixed Alkali. Lastly, as several experiments shew the Vegetable Acids to be only the Mineral Acids disguised and mortified, there are sufficient grounds for suspecting that Acids in general have a greater affinity with the Phlogiston than with Fixed Alkalis: so that instead of making an exception with regard to the Vitriolic Acid, it would perhaps be better to lay down this greater affinity as common to all Acids whatever, and to place the Phlogiston in the first column, immediately under the character which denotes an Acid in general. This theory, however, stands in need of confirmation from other experiments\*.

\* Mr. Margraaf, an able German Chymist, has made several experiments, which induce him to think that the Acid of Phosphorus is of a particular kind, and different from that of sea-salt. May it not be the Marine Acid, but altered by the union it has contracted with the phlogiston? Or may it not be, with respect to Phosphorus, what the volatile sulphureous spirit is, with respect to Sulphur? See the Memoirs of the Royal Academy of Sciences at Berlin.



Thirdly, in this same column the character of a Volatile Alkali is set above that of an Absorbent Earth, as having a greater affinity with Acids; and yet these Absorbent Earths decompose the Ammoniacal salts, drive away the Volatile Alkali from the Acids, and assume its place. This is one of the first objections made against Mr. Geoffroy's Table. His answer thereto is printed in the Memoirs of the Academy of Sciences for 1718, where his Table also is to be found. We have already declared our opinion about this matter in treating of a Volatile Alkali.

Fourthly, in 1744, Mr. Geoffroy, brother to the author of the Table, who had done no less honour to Chymistry than that eminent physician, gave in a Memoir containing an exception to the last affinity in the first column; namely, that which places Absorbent Earths above Metallic Substances. He therein shews that Alum may be converted into Copperas by boiling it in iron vessels; that on this occasion the iron precipitates the Earth of the Alum, separates it from its Acid, and assumes its place; so that of course it must have a greater affinity, than the Absorbent Earth of Alum, with the Vitriolic Acid.

At the head of the second column stands the character of the Marine Acid, which signifies that the affinities of this Acid are the subject of the column. Immediately below it is placed the mark of Tin. As this is a metalline substance, and as the first column places metalline substances in the lowest degree of affinity with all Acids, it is plain we must suppose Fixed Alkalis, Volatile Alkalis, and Absorbent Earths, to be placed here in order after the Marine Acid, and before Tin. Tin, then, is of all Metalline substances that which has the greatest affinity with the Marine Acid; and then follow Regulus of Antimony, Copper, Silver, Mercury.

Gold comes last of all; and there are no less than two vacant places above it. By this means it is in some sort excluded from the rank of substances that have an affinity with the Marine Acid. The reason thereof is that this Acid alone is not capable of dissolving Gold and combining therewith, necessarily requiring for that purpose the aid of the Nitrous Acid, or at least of the Phlogiston.

The third column exhibits the affinities of the Nitrous Acid, the character whereof stands at its head. Immediately below it is the sign of Iron, as the metal which has the greatest affinity with this Acid; and then follow other metals, each according to the degree of its relation; to wit, Copper, Lead, Mercury, and Silver. In this column, as in the preceding one, we must suppose the substances, which in the first column stand above Metallic Substances, to be placed in their proper order before Iron.

The fourth column is intended to represent the Affinities of the Vitriolic Acid. Here Mr. Geoffroy has placed the Phlogiston as the substance which has the greatest affinity with this Acid, for the reason given in our explanation of the first column. Below it he has ranked Fixed Alkalis, Volatile Alkalis, and Absorbent Earths, to shew that this is an exception to the first column. As to Metalline substances, he has set down but three, being those with which the Vitriolic Acid has the most perceptible affinity: these metals, placed in the order of their affinities, are Iron, Copper, and Silver.

The fifth column shews the affinities of Absorbent Earths. As these Earths have no sensible affinity but with Acids, this column contains only the characters of the Acids ranked according to the degree of their strength, or affinity with the Earths; to wit, the Vitriolic, the Nitrous, and the Marine

Marine Acids. Underneath this last might be placed the Acid of Vinegar, or the Vegetable Acid.

The sixth column expresses the Affinities of Fixed Alkalis with Acids, which are the same with those of Absorbent Earths. Moreover, we find Sulphur placed here below all the Acids; because Liver of Sulphur, which is a combination of Sulphur with a Fixed Alkali, is actually decomposed by any Acid: for any Acid precipitates the Sulphur and unites with the Alkali.

Immediately over the Sulphur, or in the same square with it, might be set a mark denoting the Volatile Sulphureous Spirit; because, like Sulphur, it has less affinity than any other Acid with Fixed Alkalis. Oils might also be ranked with Sulphur, because they unite with Fixed Alkalis, and therewith forms Soaps, which are decomposed by any Acid whatever.

The seventh column points out the affinities of Volatile Alkalis, which are likewise the same as those of Absorbent Earths; and the Vegetable Acid might be placed here also under the Marine Acid.

The eighth column specifies the affinities of Metallic substances with Acids. The affinities of the Acids, which with respect to Fixed Alkalis, Volatile Alkalis, and Absorbent Earths, succeeded each other uniformly, do not appear in the same order here. The Marine Acid, instead of being placed below the Vitriolic and Nitrous Acids, stands, on the contrary, at their head; because, in fact, this Acid separates Metalline substances from all the other Acids with which they happen to be united, and, forcing these Acids to quit possession, intrudes into their place. Nevertheless, it is not a general rule; for several Metalline substances must be excepted, particularly Iron and Copper.

The ninth column declares the affinities of Sulphur. Fixed Alkalis, Iron, Copper, Lead, Silver, Re-



gulus of Antimony, Mercury, and Gold, stand below it in the order of their affinities. With regard to Gold it must be observed, that it will not unite with pure Sulphur: it suffers itself to be dissolved only by the Liver of Sulphur, which is known to be a composition of Sulphur and Fixed Alkali.

At the head of the tenth column appears Mercury, and beneath it several Metalline substances, in the order of their affinities with it. Those Metalline substances are Gold, Silver, Lead, Copper, Zinc, and Regulus of Antimony.

It is proper to remark on this column that Regulus of Antimony, which stands the lowest, unites but very imperfectly with Mercury; and that after a seeming union of these two Metallic substances hath been obtained, by a tedious triture with the addition of water, they do not continue long united, but spontaneously separate from each other in a short time. Iron and Tin are here excluded; the former with great reason, because hitherto it hath not been clearly proved, by any known experiment, that ever Mercury was united with Iron: but the same objection cannot be made to Tin, which amalgamates very well with Mercury, and might therefore be placed in this column nearly between Lead and Copper. I use the word *nearly*, because the different degrees of affinity between Metalline substances and Mercury are not so exactly determined, as the other relations before considered; seeing they generally unite with it, without excluding one another. We can therefore scarce judge of the degree of affinity that belongs to each, but by the greater or less readiness of each to amalgamate therewith.

The eleventh column shews that Lead has a greater affinity with Silver than with Copper.

The twelfth, that Copper has a greater affinity with Mercury than with Calamine.

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The thirteenth, that Silver has a greater affinity with Lead than with Copper.

The fourteenth contains the affinities of Iron. Regulus of Antimony stands immediately underneath it, as being the Metallic substance which has the greatest affinity with it. Silver, Copper, and Lead are placed together in the next square below, because the degrees of affinity which those Metals have with Iron are not exactly determined.

The same is to be said of the fifteenth column: Regulus of Antimony stands at its head; Iron is immediately below it; and below the Iron the same three Metals occupy one square as before.

Lastly, the sixteenth column indicates that Water has a greater affinity with Spirit of Wine than with Salts. By this general expression must not be understood any Saline substance whatever; but only the Neutral Salts, which Spirit of Wine frees from the water that kept them in solution. Fixed Alkalis, on the contrary, as well as the Mineral Acids, have a greater affinity than Spirit of Wine with Water: so that these Saline substances, being well dephlegmated, and mixed with Spirit of Wine, imbibe the water it contains and rectify it.

To these might be added another short column, having Spirit of Wine at its head: immediately below it should be the character of Water, and below that the mark of Oil. This column would shew that Spirit of Wine has a greater affinity with Water than with Oils; because any Oily matter whatever, that is dissolved in Spirit of Wine, may be actually separated from it by the affusion of Water. This rule admits of no exception but in one case; which is when the oily substance partakes of the nature of soap, by having contracted an union with some saline matter. But as this must be imputed wholly to that adventitious saline matter being superadded to the oily substance, it is no just founda-

dation for an exception, and the affinity in question is nevertheless general.

We have now delivered every thing material that we had to say concerning Mr. Geoffroy's Table of Affinities. It is, as we observed before, of exceeding great service, as it collects into one view the principal truths laid down in this Treatise. Indeed the most advantageous way of using it is, not to delay consulting it till you have read the book through, but to turn to it while you are reading, as oft as any affinity between bodies is treated of; which it will imprint more strongly on your mind, by representing it in a manner before your eyes.

## CH A P. XVIII.

### *The THEORY of CONSTRUCTING the VESSELS most commonly used in CHYMISTRY.*

**C**HYMISTS cannot perform the operations of their art without the help of a considerable number of vessels, instruments, and furnaces, adapted to contain the bodies on which they intend to work, and to apply to them the several degrees of heat required by different processes. It is therefore proper, before we advance to the operations themselves, to consider particularly and minutely what relates to the instruments with which they are to be performed.

Vessels intended for Chymical Operations should, to be perfect, be able to bear, without breaking, the sudden application of great heat and great cold; be impenetrable to every thing, and unalterable by any solvent; unvitriifiable, and capable of enduring  
the



the most violent fire without melting: but hitherto no vessels have been found with all these qualities united.

They are made of sundry materials; namely, of metal, of glass, and of earth. Metalline vessels, especially those made of Iron or Copper, are apt to be corroded by almost every saline, oily, or even aqueous substance. For this reason, in order to render the use of them a little more extensive, they are tinned on the inside. But, notwithstanding this precaution, they are on many occasions not to be trusted; and should never be employed in any nice operations which require great accuracy: they are, moreover, incapable of resisting the force of fire.

Earthen vessels are of several sorts. Some, that are made of a refractory earth, are capable of being suddenly exposed to a strong fire without breaking, and even of sustaining a great degree of heat for a considerable time: but they generally suffer the vapours of the matters which they contain, as well as vitrified metals, to pass through them, especially the glass of lead, which easily penetrates them and runs through their pores as through a sieve. There are others made of an earth that, when well baked, looks as if it were half vitrified: these being much less porous, are capable of retaining the vapours of the matters which they contain, and even glass of lead in fusion; which is one of the severest trials a vessel can be put to: but then they are more brittle than the other sort.

Good glass vessels should constantly be employed in preference to all others, whenever they can possibly be used: and that not only because they are noway injured by the most active solvents, nor suffer any part of what they contain to pass through, but also because their transparency allows the Chymist to observe what passes within them: which is  
always

always both curious and useful. But it is pity that vessels of this sort should not be able to endure a fierce fire without melting. We shall take care, when we come to describe the several sorts of chymical instruments, and the manner of using them, to note what vessels are to be preferred to others on different occasions.

Distillation, as hath been already said, is an operation by which we separate from a body, by the help of a gradual heat, the several principles of which it consists.

There are three methods of distilling. The first is performed by applying the heat over the body whose principles are to be extracted. In this case, as the liquors, when heated and converted into vapours, constantly endeavour to fly from the center of heat, they are forced to re-unite in the lower part of the vessel, that contains the matter in distillation, and so passing through the pores or holes of that vessel, they fall into another cold vessel applied underneath to receive them. This way of distilling is on this account called Distilling *per Descensum*. It requires no other apparatus than two vessels figured like segments of hollow spheres, whereof that which is pierced with little holes, and intended to contain the matter to be distilled, should be much less than the other, which is to contain the fire, and to fill its aperture exactly; the whole together being supported vertically upon a third vessel, which is to serve the purpose of a recipient, admitting into its mouth the convex bottom of the vessel containing the matter to be distilled, which must accurately fill it. This method of distilling is but little used.

The second method of distilling is performed by applying the heat underneath the matter to be decomposed. On this occasion the liquors being heated, rarefied, and converted into vapours, rise  
and

and are condensed in a vessel contrived for that purpose, which we shall presently describe. This way of distilling is called Distilling *per Ascensum*, and is much used.

The vessel in which this distillation *per Ascensum* is performed we call an *Alembic*.

There are several sorts thereof differing from one another both in the matter of which, and the manner in which, they are made.

Those employed to draw the odoriferous waters and essential oils of plants are generally made of copper, and consist of several pieces. The first, which is designed to contain the plant, is formed nearly like a hollow cone, the vertex whereof is drawn out in the shape of a hollow cylinder or tube: this part is named the *Cucurbit*, and its tube the *Neck* of the *Alembic*. To the upper end of this tube another vessel is soldered: this is called the *Head*, and commonly has likewise the form of a cone, joined to the neck of the alembic by its base, round which, on the inside, is hollowed a small groove, communicating with an orifice that opens at its most depending part. To this orifice is soldered a small pipe in a direction sloping downwards, which is called the *Nose*, *Spout*, or *Beak* of the alembic.

As soon as the matters contained in the alembic grow hot, vapours begin to arise from them, and ascending through the neck of the alembic into the head, are by the sides thereof stopped and condensed: from whence they trickle down in little streams to the groove, which conveys them to the spout; and by that they pass out of the alembic into a glass vessel with a long neck, the end of the spout being introduced into that neck, and luted thereto.

To facilitate the refrigeration and condensation of the vapours circulating in the head, all alembics of metal are moreover provided with another piece, which is a kind of large pan of the same metal,  
fitted



fitted and soldered round the head. This piece serves to keep cold water in, which incessantly cools the head, and therefore it is called the *Refrigeratory*. The water in the refrigeratory itself grows hot after some time, and must therefore be changed occasionally; the heated water being first drawn off by means of a cock fixed near the bottom of the refrigeratory. All copper alembics should be tinned on the inside for the reasons already given.

When saline spirits are to be distilled, alembics of metal must not be used, because the saline vapours would corrode them. In this case recourse must be had to alembics of glass. These consist of two pieces only; namely, a *Cucurbit*, whose superiour orifice is admitted into and exactly luted with its *Head*, which is the second piece.

In general, as alembics require that the vapours of the matter to be distilled should rise to a considerable height, they ought to be used only when the most volatile principles are to be drawn from bodies: and the lighter and more volatile the substances to be separated by distillation are, the taller must the alembic be; because the most ponderous parts, being unable to rise above a certain height, fall back again into the cucurbit as soon as they arrive there, leaving the lighter to mount alone, whose volatility qualifies them to ascend into the head.

When a matter is to be distilled, that requires a very tall alembic, and yet does not admit of a metalline vessel, the end will be best answered by a glass vessel of a round or oval shape, having a very long neck, with a small head fitted to its extremity. Such a vessel serves many purposes: it is sometimes employed as a receiver, and at other times as a digesting vessel; on which last occasion it goes under the name of a *Matrafs*.

When

When one of these provided with a head is applied to the purpose of distilling, it forms a sort of alembic.

There are some alembics of glass, blown in such a manner by the workmen, that the body and head form but one continued piece. As these alembics do not stand in need of having their several pieces luted together, they are very useful on some occasions, when such exceeding subtile vapours rise as are capable of transpiring through lutes. The head must have an aperture at the top, provided with a short tube, through which by means of a funnel with a long pipe, the matter to be distilled may be introduced into the cucurbit. This is to be exactly closed with a glass stopple, the surface whereof must be made to fit the inside of the tube in every point, by rubbing those two pieces well together with emery.

Another sort of alembic hath also been invented, which may be used with advantage when *Cohobation* is required; that is, when the liquor obtained by distillation is to be returned upon the matter in the cucurbit; and especially when it is intended that this cohobation shall be repeated a great number of times. The vessel we are speaking of is constructed exactly in the same manner as that last described; except that its beak, instead of being in a straight line, as in the other alembics, forms a circular arch, and re-enters the cavity of the cucurbit, in order to convey back again the liquor collected in the head. This instrument hath commonly two beaks opposite to each other, both turned in this manner, and is called a *Pelican*: it saves the artist the trouble of frequently unluting and reluting his vessels, as well as the loss of a great many vapours.

There are certain substances which in distillation afford matters in a concrete form, or rise wholly in the form of a very light powder, called *Flowers*.

When such substances are to be distilled, the cucurbit which contains them is covered with a head without a nose, which is named a *Blind-head*.

When the flowers rise in great quantities and very high, a number of heads is employed to collect them; or rather a number of a kind of pots, consisting of a body only without any bottom, which fitting one into the other form a canal, that may be lengthened or shortened at pleasure, according as the flowers to be sublimed are more or less volatile. The last of the heads, which terminates the canal, is quite close at one end, and makes a true blind-head. These vessels are called *Aludels*: they are usually of earthen or stone ware.

All the vessels above-mentioned are fit only for distilling such light volatile matters as can be easily raised and brought over; such as phlegm, essential oils, fragrant waters, acid oily spirits, volatile alkalis, &c. But when the point is to procure by distillation principles that are much less volatile, and incapable of rising high, such as the thick fetid oils; the vitriolic, the nitrous, and the marine acids, &c. we are under a necessity of having recourse to other vessels, and another manner of distilling.

It is easy to imagine that such a vessel must be much lower than the alembic. It is indeed no more than a hollow globe, whose upper part degenerates into a neck or tube, that is bent into a horizontal position; for which reason this instrument is called a *Retort*: it is always of one single piece.

The matter to be distilled is introduced into the body of the retort by means of a ladle with a long tubular shank. Then it is set in a furnace built purposely for this use, and so that the neck of the retort coming out of the furnace may, like the nose of the alembic, stand in a sloping position, to facilitate the egress of the liquors, which by its means are conveyed



conveyed to a receiver, into which it is introduced, and with which it is luted. This way of distilling, in which the vapours seem rather to be driven out of the vessel horizontally and laterally, than raised up and sublimed, is for that reason called *Distillation per Latus*.

Retorts are, of all the instruments of distillation, those that must sustain the greatest heat, and resist the strongest solvents; and therefore they must not be made of metal. Some however, which are made of iron may do well enough on certain occasions: the rest are either of glass or earth. Those of glass, for the reasons above given, are preferable to the other sort, in all cases where they are not to be exposed to such a force of fire as may melt them. The best glass, that which stands both heat and solvents best, is that in which there are fewest alkaline salts. Of this sort is the green German glass: the beautiful white crystal glass is far from being equally serviceable.

Retorts, as well as alembics, may be of different forms. For example, some matters are apt to swell, and rise over the neck of the retort in substance, without suffering any decomposition; when such matters are to be distilled in a retort, it is proper that the body of the vessel, instead of being globular, be drawn out into the form of a pear, so as nearly to resemble that of a cucurbit. In a retort of this kind, the distance between the bottom and the neck being much greater than in those whose bodies are spherical, the matters contained have much more room for expansion; so that the inconvenience here mentioned is thereby prevented. Retorts of this form are called English retorts. As they hold the middle place between alembics, and common retorts, they may be used to distil such matters as have a mean degree of volatility between the greatest and the least.

It is moreover proper to have, in a laboratory; sundry retorts with necks of different diameters. Wide necks will be found the fittest for conveying thick matters, and such as readily become fixed; for instance, some very thick fetid oils; butter of antimony, &c.: for as these matters acquire a consistence as soon as they are out of the reach of a certain degree of heat, they would soon choak a narrow neck, and by stopping the vapours, which rise at the same time from the retort, might occasion the bursting of the vessels.

Some retorts are also made with an opening on their upper side, like that of tubulated glass alembics, which is to be closed in the same manner with a glass stopple. These retorts are also called Tubulated retorts, and ought always to be used whenever it is necessary to introduce fresh matter into the retort during the operation; seeing it may be done by means of this invention, without unluting and reluting the vessels; which ought always to be avoided as much as possible.

One of the things that most perplexes the Chymists, is the prodigious elasticity of many different vapours, which are frequently discharged with impetuosity during the distillation, and are even capable of bursting the vessels with explosion, and with danger to the artist. On such occasions it is absolutely necessary to give these vapours vent, as we shall direct in its proper place: but as that can never be done without losing a great many of them; as some of them in particular are so elastic that scarce any at all would remain in the vessel; for instance, those of the spirit of nitre, and especially those of the smoking spirit of salt; the practice is to make use of very large receivers, of about eighteen or twenty inches diameter, that the vapours may have sufficient room to circulate in, and by applying to the wide surface presented them by the extensive

five

live inside of such a large vessel, may be condensed into drops. These huge receivers are commonly in the form of hollow globes, and are called Ballons.

To give these vapours still more room, ballons have been contrived with two open gullets in each, diametrically opposite to one another; whereof one admits the neck of the retort, and the other is received by one of the gullets of a second ballon of the same form, which is joined in like manner to a third, and so on. By this artifice the space may be enlarged at pleasure. These ballons with two necks are called Adopters.

Operations on bodies that are absolutely fixed, as metals, stones, sand, &c. require only such vessels as are capable of containing those bodies, and resisting the force of fire. These vessels are little hollow pots, of different dimensions, which are called Crucibles. Crucibles can hardly be made of any thing but earth; they ought to have a cover of the same material fitted to shut them close. The best earth we know is that whereof those pots are made in which butter is brought from Bretagne: these pots themselves are exceeding good crucibles; and they are almost the only ones that are capable of holding glass of lead in fusion, without being penetrated by it.

For the roasting of ores, that is, freeing them, by the help of fire, from their sulphureous and arsenical parts, little cups made of the same material with crucibles are used; but they are made flat, shallow, and wider above than below, that these volatile matters may the more freely exhale. These vessels are called Tests, or Scorifiers: they are scarce ever used but in the Docimastic art, that is, in making small Assays of ores.



## C H A P. XIX.

*The* THEORY of CONSTRUCTING *the*  
FURNACES *most commonly used in*  
CHYMISTRY.

**S**KILL in conducting and applying fire properly, and determining its different degrees, is of very great consequence to the success of Chymical operations.

As it is exceeding difficult to govern and moderate the action of fire, when the vessels in which any operation is performed are immediately exposed to it, Chymists have contrived to convey heat to their vessels, in nice operations, through different mediums, which they place occasionally between those vessels and the fire.

Those intermediate substances in which they plunge their vessels are called Baths. They are either fluid or solid: the fluid baths are water or its vapours. When the distilling vessel is set in water, the bath is called *Balneum Mariæ*, or the *Water-Bath*; and the greatest degree of heat of which it is susceptible is that of boiling water. When the vessel is exposed only to the vapours which exhale from water; this forms the *Vapour-Bath*; the heat of which is nearly the same with that of the *Balneum Mariæ*. These baths are useful for distilling essential oils, ardent spirits, sweet-scented waters; in a word, all such substances as cannot bear a greater heat, without prejudice either to their odour, or to some of their other qualities.

Baths

Baths may also be made of any other fluids, such as oils, mercury, &c. which are capable of receiving and communicating much more heat: but they are very seldom used. When a more considerable degree of heat is required, a bath is prepared of any solid matter reduced to a fine powder; such as sand, ashes, filings of iron, &c. The heat of these baths may be pushed so far as to make the bottom of the vessel become faintly red. By plunging a thermometer into the bath, by the side of the vessel, it is easy to observe the precise degree of heat applied to the substance on which you are working. It is necessary that the thermometers employed on this occasion be constructed on good principles, and so contrived as to be easily compared with those of the most celebrated natural philosophers. Those of the illustrious Réaumur are most used and best known, so that it would not be amiss to give them the preference. When a greater heat is required than any of those baths can give, the vessels must be set immediately on live coals, or in a flaming fire: this is called working with a naked fire; and in this case it is much more difficult than in the other to determine the degrees of heat.

There are several ways of applying a naked fire. When the heat or flame is reflected upon the upper part of a vessel which is exposed to the fire, this is called a Reverberated heat. A Melting heat is that which is strong enough to fuse most bodies. A Forging heat is that of a fire which is forcibly excited by the constant blast of a pair of bellows, or more.

There is also another sort of fire which serves very commodiously for many operations, because it does not require to be fed or frequently mended: this is afforded by a lamp with one or more wicks, and may be called a Lamp-heat. It is scarce ever employed but to heat baths, in operations which require a gentle and long continued

warmth: if it hath any fault, it is that of growing gradually hotter.

All the different ways of applying fire require Furnaces of different constructions: we shall therefore describe such as are of principal and most necessary use.

Furnaces must be divided into different parts or stories, each of which has its particular use and name.

The lower part of the furnace designed for receiving the ashes, and giving passage to the air, is called the Ash-hole. The ash-hole is terminated above by a Grate, the use of which is to support the coals and wood, which are to be burnt thereon: this part is called the Fire-place. The fire-place is in like manner terminated above by several iron bars, which lie quite across it from right to left, in lines parallel to each other: the use of these bars is to sustain the vessels in which the operations are to be performed. The space above these bars to the top of the furnace is the upper story, and may be called the Laboratory of the furnace. Lastly, some furnaces are quite covered above by means of a kind of vaulted roof called the dome.

Furnaces have moreover several apertures: one of these is at the ash-hole, which gives passage to the air, and through which the ashes that fall through the grate are raked out; this aperture is called the ash-hole door: another is at the fire-place, through which the fire is supplied with fuel, as occasion requires; this is called the mouth or door of the fire-place, or the stoke-hole: there is a third in the upper story, through which the neck of the vessel passes; and a fourth in the dome for carrying off the fuliginosities of combustible matters, which is called the chimney.

To conclude, there are several other openings in the several parts of the furnace, the use whereof



is to admit the air into those places, and also, as they can be easily shut, to incite or slacken the activity of the fire; and so to regulate it; which has procured them the title of registers. All the other openings of the furnace should be made to shut very close, the better to assist in governing the fire; by which means they likewise do the office of registers.

In order to our forming a just and general idea of the construction of furnaces, and of the disposition of the several apertures in them, with a view to increase or diminish the activity of the fire, it will be proper to lay down, as our ground-work, certain principles of natural philosophy, the truth of which is demonstrated by experience.

And first, every body knows that combustible matters will not burn or consume unless they have a free communication with the air; insomuch that if they be deprived thereof, even when burning most rapidly, they will be extinguished at once: that consequently combustion is greatly promoted by the frequent accession of fresh air, and that a stream of air, directed so as to pass with impetuosity through burning fuel, excites the fire to the greatest possible activity.

Secondly, it is certain that the air which touches, or comes near ignited bodies is heated, rarefied, and rendered lighter than the air about it, that is, further distant from the center of heat; and consequently that this air, so heated and become lighter, is necessarily determined thereby to ascend and mount aloft, in order to make room for that which is less heated and not so light, which by its weight and elasticity tends to occupy the place quitted by the other. Another consequence hereof is, that if the fire be kindled in a place inclosed every where but above and below, a current of air will be formed in that place, running in a direction

tion from the bottom to the top; so that if any light bodies be applied to the opening below, they will be carried up towards the fire; but, on the contrary, if they be held at the opening above, they will be impelled by a force which will drive them up and carry them away from the fire.

Thirdly and lastly, it is a truth demonstrated in hydraulics that the velocity of a given quantity of any fluid, determined to flow in any direction whatever, is so much the greater the narrower the channel is to which that fluid is confined; and consequently that the velocity of a fluid will be increased by making it run from a wider through a narrower passage.

These principles being established, it is easy to apply them to the construction of furnaces. First, if a fire be kindled in the fire-place of a furnace, which is open on all sides, it burns nearly as if it were in the open air. It has with the surrounding air a free communication; so that fresh air is continually admitted to facilitate the entire combustion of the inflammable matters employed as fuel. But there being nothing to determine that air to pass with rapidity through the fire in this case, it does not at all augment the activity thereof, but suffers it to waste away quietly.

Secondly, if the ash-hole or dome of a furnace, in which a fire is burning, be shut quite close, then there is no longer any free communication between the air and the fire: if the ash-hole be shut, the air is debarred from having free access to the fire; if the dome be stopt, the egress of the air rarefied by the fire is prevented; and consequently the fire must in either case burn very faintly and slowly, gradually die away, and at last go quite out.

Thirdly, if all the openings of the furnace be wholly closed, it is evident that the fire will be very quickly extinguished.

Fourthly,

Fourthly, if only the lateral openings of the fire-place be shut, leaving the ash-hole and upper part of the furnace open; it is plain that the air entering by the ash-hole will necessarily be determined to go out at top, and that consequently a current of air will be formed, which will pass through the fire, and make it burn briskly and vigorously.

Fifthly, if both the ash-hole and the upper story of the furnace be of some length, and form canals either cylindric or prismatic, then the air being kept in the same direction through a longer space, the course of its stream will be both stronger and better determined, and consequently the fire will be more animated by it.

Sixthly and lastly, if the ash-hole and the upper part of the furnace, instead of being cylindric or prismatic canals, have the form of truncated cones or pyramids, standing on their bases, and so ordered that the upper opening of the ash-hole, adjoining to the fire-place, may be wider than the base of the superiour cone or pyramid, then the stream of air, being forced to pass incessantly from a larger channel through a smaller, must be considerably accelerated, and procure to the fire the greatest activity which it can receive from the make of a furnace.

The materials fittest for building furnaces are, 1. Bricks, joined together with potters clay mixed with sand and moistened with water. 2. Potters clay mingled with potsherds, moistened with water, and baked in a violent fire. 3. Iron; of which all furnaces may be made, with this precaution, that the inside be provided with a great many prominent points, as fastenings for a coat of earth, with which the internal parts of the furnace must necessarily be covered to defend it from the action of the fire,



The reverberating furnace is one of those that are most employed in Chymistry: it is proper for distillations by the retort, and should be constructed in the following manner.

First, the use of the ash-hole being, as was said, to give passage to the air and to receive the ashes, no bad consequence can attend its being made pretty high: it may have from twelve to twenty or twenty-four inches in height. Its apertures should be wide enough to admit billets of wood, when a great fire is to be made.

Secondly, the ash-hole must be terminated at its upper part by an iron grate, the bars of which should be very substantial, that they may resist the action of the fire: this grate is the bottom of the fire-place, and destined to support the coals. In the lateral part of the fire-place, and nearly about the same height with the grate, there should be a hole of such a size that it may easily admit charcoal, as well as little tongs and shovels for managing the fire. This aperture or mouth of the fire-place should be perpendicularly over the mouth of the ash-hole.

Thirdly, from six to eight or ten inches high above the grate over the ash hole, little apertures must be made in the walls of the furnace, of eight or ten lines in diameter, an inch from one another, and those in one side must be diametrically opposite to those in the other. The use of these holes is to receive bars of iron for the retort to rest on; which should be, as I said, at different heights, in order to accommodate retorts of different sizes. At the upper extremity of this part of the furnace, which reaches from the iron bars to the top, the height whereof should be somewhat less than the width of the furnace, must be cut a semi-circular aperture for the neck of the retort to come through. This hole must by no means be over the doors of the fire-place and ash-hole; for then, as it gives passage to the neck

neck of the retort, it must of course be opposite to the receiver, and in that case the receiver itself would stand over against those two apertures; which would be attended with this double inconvenience, that the receiver would not only grow very hot, but greatly embarrass the operator, whose free access to the fire-place and ash-hole would be thereby obstructed. It is proper therefore that the semi-circular cut we are speaking of be so placed, that when the greatest ballons are luted to the retort, they may leave an open passage to the fire-place and ash-hole.

Fourthly, in order to cover in the laboratory of the reverberating furnace, there must be a roof made for it in the form of a cupola, or concave hemisphere, having the same diameter as the furnace. This dome should have a semi-circular cut in its rim answering to that above-directed to be made in the upper extremity of the furnace, so that, when adjusted to each other, the two together may form a circular hole for the neck of the retort to pass through. At the top of this dome there must also be a circular hole of three or four inches diameter, carrying a short tapering funnel of the same diameter, and three inches high, which will serve for a chimney to carry off all fuliginosities, and accelerate the current of the air. This passage may be shut at pleasure with a flat cover. Moreover, as it is necessary that the dome should be taken off and put on with ease, it should have two ears or handles for that purpose: a portative or moveable furnace should also have a pair of handles, fixed opposite to each other, between the ash-hole and the fire-place.

Sixthly and lastly, a conical canal must be provided of about three feet long, and sufficiently wide at its lower end to admit the funnel of the aperture at the top of the dome. This conical tube is to be applied to the dome when the fire is required to be  
extremely

extremely active : it tapers gradually from its base upwards, and breaks off as if truncated at top, where it should be about two inches wide.

Besides the apertures already mentioned as necessary for a reverberating furnace, there must also be many other smaller holes made in its ash-hole, fire-place, laboratory, and dome, which must all be so contrived as to be easily opened and shut with stopples of earth : these holes are the registers of the furnace, and serve to regulate the activity of the fire, according to the principles before laid down.

When the action of the fire is required to be exactly uniform and very brisk, it is necessary to stop carefully with moist earth all the little chinks in the juncture of the dome with the furnace, between the neck of the retort and the circular hole through which it passes, and which it never fills exactly ; and lastly, the holes which receive the iron bars that sustain the retort.

It is proper to have, in a laboratory, several reverberating furnaces of different magnitudes ; because they must be proportioned to the size of the retorts employed. The retort ought to fill the furnace, so as to leave only the distance of an inch between it and the inside of the furnace.

Yet when the retort is to be exposed to a most violent fire, and especially when it is required that the heat shall act with equal force on all parts of the furnace, and as strongly on its vault as on its bottom, a greater distance must be left between the retort and the inside of the furnace ; for then the furnace may be filled with coals, even to the upper part of the dome. If moreover some pieces of wood be put into the ash-hole, the conical canal fitted on to the funnel of the dome, and all the apertures of the furnace exactly closed, except the ash-hole and the chimney, the greatest heat will then be excited that this furnace can produce.

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The furnace now described may also be employed in many other chymical operations. If the dome be laid aside, an alembic may very well be placed therein: but then the space, which will be left between the body of the alembic and the top of the upper part of the furnace, must be carefully filled up with Windsor-loam moistened; for without that precaution the heat would soon reach the very head, which ought to be kept as cool as possible, in order to promote the condensation of the vapours. On this occasion therefore it will be proper to leave no holes open in the fire-place, but the lateral ones; of which also those over-against the receiver must be stopped.

A pot, or broad-brimmed earthen pan, may be placed over this furnace, and being so fitted to it as to close the upper part thereof accurately, and filled with sand, may serve for a sand-heat to distil with.

The bars designed to support distilling vessels being taken out, a crucible may stand therein, and many operations be performed that do not require the utmost violence of fire. In a word, this furnace is one of the most commodious that can be, and more extensively useful than any other.

The Melting furnace is designed for applying the greatest force of heat to the most fixed bodies, such as metals and earths. It is never employed in distilling: it is of nouse but for calcination and fusion; and consequently need not admit any vessels but crucibles.

The ash-hole of this furnace differs from that of the reverberating furnace only in this, that it must be higher, in order to raise the fire-place to a level with the artist's hand; because in that all the operations of this furnace are performed. The ash-hole therefore must be about three feet high: and this height procures it moreover the advantage of a good draught

draught of air. For the same reason, and in consequence of the principles we laid down, it should be so built that its width lessening insensibly from the bottom to the top, it may be narrower where it opens into the fire-place than any where below.

The ash-hole is terminated at its upper end, like that of the reverberating furnace, by a grate, which serves for the bottom of the fire-place, and ought to be very substantial that it may resist the violence of the fire. The inside of this furnace is commonly an elliptic curve; because it is demonstrated by mathematicians that surfaces having that curvature reflect the rays of the sun, or of fire, in such a manner that meeting in a point, or a line, they produce there a violent heat. But to answer this purpose those surfaces must be finely polished; an advantage hardly procurable to the internal surface of this furnace, which can be made of nothing but earth: besides, if it were possible to give it a polish, the violent action of the fire that must be employed in this furnace would presently destroy it. Yet the elliptical figure must not be entirely disregarded: for, if care be taken to keep the internal surface of the furnace as smooth as possible, it will certainly reflect the heat pretty strongly, and collect it about the center.

The fire-place of this furnace ought to have but four apertures.

First, that of the lower grate, which communicates with the ash-hole.

Secondly, a door in its fore-side, through which may be introduced coals, crucibles, and tongs for managing them: this aperture should be made to shut exactly with a plate of iron, having its inside coated with earth, and turning on two hinges fixed to the furnace.

Thirdly, over this door a hole slanting downwards, towards the place where the crucible is to

stand. The use of this hole is to give the operator an opportunity of examining the condition of the matters contained in his crucible, without opening the door of the fire-place: this hole should be made to open and shut easily, by means of a stopple of earth.

Fourthly, a circular aperture of about three inches wide in the upper part or vault of the furnace, which should gradually lessen and terminate, like that of the dome of the reverberating furnace, in a short conical funnel of about three inches long, and fitted to enter the conical pipe before described, which is applied when the activity of the fire is to be increased.

When this furnace is to be used, and a crucible to be placed in it, care must be taken to set on the grate a cake of baked earth, somewhat broader than the foot of the crucible. The use of this stand is to support the crucible, and raise it above the grate, for which purpose it should be two inches thick. Were it not for this precaution the bottom of the crucible, which should stand immediately on the grate, could never be thoroughly heated, because it would be always exposed to the stream of cold air which enters by the ash-hole. Care should also be taken to heat this earthen bottom red-hot before it be placed in the furnace, in order to free it from any humidity, which might otherwise happen to be driven against the crucible during the operation, and occasion its breaking.

We omitted to take notice in speaking of the ash-hole that, besides its door, it should have about the middle of its height a small hole, capable of receiving the nosel of a good perpetual bellows, which is to be introduced into it and worked, after the door is exactly shut, when it is thought proper to excite the activity of the fire to the utmost violence.

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The Forge is only a mass of bricks of about three feet high, along whose upper surface is directed the nose or pipe of a pair of large perpetual bellows, so placed that the operator may easily blow the fire with one hand. The coals are laid on the hearth of the forge, near the nose of the bellows; they are confined, if necessary, to prevent their being carried away by the wind of the bellows, within a space inclosed by bricks; and then by pulling the bellows the fire is continually kept up in its greatest activity. The forge is of use when there is occasion to apply a great degree of heat suddenly to any substance, or when it is necessary that the operator be at liberty to handle frequently the matters which he proposes to fuse or calcine.

The Cupelling furnace is that in which gold and silver are purified, by the means of lead, from all alloy of other metallic substances. This furnace must give a heat strong enough to vitrify lead, and therewith all the alloy which the perfect metals may contain. This furnace is to be built in the following manner.

First, of thick iron-plates, or of some such composition of earth as we recommended for the construction of furnaces, must be formed a hollow quadrangular prism, whose sides may be about a foot broad, and from ten to eleven inches high; and extending from thence upwards may converge towards the top, so as to form a pyramid truncated at the height of seven or eight inches, and terminated by an aperture of the width of seven or eight inches every way. The lower part of the prism is terminated, and closed, by a plate of the same materials of which the furnace is constructed.

Secondly, in the fore-side or front of this prism there is an opening of three or four inches in height

height by five or six inches in breadth: this opening, which should be very near the bottom, is the door of the ash-hole. Immediately over this opening is placed an iron grate, the bars of which are quadrangular prisms of half an inch square, laid parallel to each other, and about eight or nine inches asunder, and so disposed that two of their angles are laterally opposite, the two others looking one directly upwards and the other downwards. As in this situation the bars of the grate present to the fire-place very oblique surfaces, the ashes and very small coals do not accumulate between them, or hinder the free entrance of the air from the ash-hole. This grate terminates the ash-hole at its upper part, and serves for the bottom of the fire-place.

Thirdly, three inches, or three and a half, above the grate, there is in the fore-side of the furnace another opening terminated by an arch for its upper part, which consequently has the figure of a semi-circle: it ought to be four inches wide at bottom, and three inches and an half high at its middle. This opening is the door of the fire-place; yet it is not intended for the same uses as the door of the fire-place in other furnaces: the purpose for which it is actually destined shall be explained when we come to shew how the furnace is to be used. An inch above the door of the fire-place, still in the fore-side of the furnace, are two holes of about an inch diameter, and at the distance of three inches and a half from each other, to which answer two other holes of the same size, made in the hinder part, directly opposite to these. There is moreover a fifth hole of the same width about an inch above the door of the fire-place. The design of all these holes shall be explained when we describe the manner in which these furnaces are to be used.

Fourthly, the fore-part of the furnace is bound by three iron braces, one of which is fixed just below the door of the ash-hole; the second occupies the whole space between the ash-hole door and the door of the fire-place, and has two holes in it, answering to those which we directed to be made in the furnace itself about this place; and the third is placed immediately over the door of the fire-place. These braces must extend from one corner of the front of the furnace to the other, and be fastened thereto with iron pins, in such a manner that their sides next to the doors may not lie quite close to the body of the furnace, but form a kind of grooves for the iron plates to slide in, that are designed to shut the two doors of the furnace when it is necessary. Each of these iron plates should have a handle, by which it may be conveniently moved; and to each door there should be two plates, which meeting each other, and joining exactly in the middle of the door-place, may shut it very close. Each of the two plates belonging to the door of the fire-place ought to have a hole in its upper part; one of these holes should be a slit of about two lines wide, and half an inch long; the other may be a semi-circular opening of one inch in height and two in breadth. These holes should be placed so that neither of them may open into the fire-place when the two plates are joined together in the middle of the door, to shut close.

Fifthly, to terminate the furnace above, there must be a pyramid formed of the same materials with the furnace, hollow, quadrangular, three inches high on a base of seven inches, which base must exactly fit the upper opening of the furnace: the top of this pyramidal cover must end in a tube of three inches in diameter and two in height, which must be almost cylindrical, and yet a little inclining to the conical form. This tube serves,



as in the furnaces already described, to carry the conical funnel, which is fitted to the upper part when a fire of extraordinary activity is wanted.

The furnace thus constructed is fit to serve all the purposes for which it is designed: yet before it can be used another piece must be provided, which, though it does not properly belong to the furnace, is nevertheless necessary in all the operations performed by it; and that is a piece contrived to contain the cupels, or other vessels which are to be exposed to the fire in this furnace. It is called a Muffle, and is made in the following manner.

On an oblong square, of four inches in breadth, and six or seven in length, a concave semi-cylinder is erected, in the form of a vault, which makes a semi-circular canal, open at both ends. One of these is almost entirely closed, except that near the bottom two small semi-circular holes are left. In each of its sides likewise two such holes are made, and the other end is left quite open.

The Muffle is intended to bear and communicate the fiercest heat; and therefore it must be made thin, and of an earth that will resist the violence of fire, such as that of which crucibles are made. The Muffle being thus constructed, and then well baked, is fit for use.

When it is to be used it must be put into the furnace by the upper opening, and set upon two iron bars, introduced through the holes made for that purpose below the door of the fire-place. The Muffle must be placed on these bars in the fire-place in such a manner that its open end shall stand next to, and directly against, the door of the fire-place, and may be joined to it with lute. Then the cupels are ranged in it, and the furnace is to be filled up, to the height of two or three inches above the Muffle, with small coals not bigger than a walnut, to the end that they may lie close round the Muffle, and

procure it an equal heat on every side. The chief use of the Muffle is to prevent the coals and ashes from falling into the cupels, which would be very prejudicial to the operations carrying on in them: for the lead would not vitrify as it ought, because the immediate contact of the coals would continually restore its phlogiston; or else the glass of lead, which ought to penetrate and pass through the cupels, would be rendered incapable of so doing; because the ashes mixing therewith would give it such a consistence and tenacity as would destroy that property, or at least considerably lessen it. The openings therefore, which are left in the lower part of the Muffle, should not be so high as to admit coals or ashes to get into the cupels; the use of them is to procure an easier passage for the heat and the air to those vessels. The Muffle is left quite open in its fore-part, that the operator may be at liberty to examine what passes in the cupels, to stir their contents, to remove them from one place to another, to convey new matters into them, &c. and also to promote the free access of the air, which must concur with the fire towards the evaporation necessary to the vitrification of lead; which air, if fresh were not often enough admitted, would be incapable of producing that effect; because it would soon be loaded with such a quantity of vapours that it could not take up any more.

The government of the fire in this furnace is founded on the general principles above laid down for all furnaces. Yet as there are some little differences, and as it is very essential to the success of the operations for which this furnace is intended, that the artist should be absolutely master of his degree of heat, we shall in a few words shew how that may be raised or lowered.

When the furnace is filled with coals and kindled, if the door of the ash-hole be set wide open, and that

that of the fire-place shut very close, the force of the fire is increased; and if moreover the pyramidal cover be put on the top, and the conical funnel added to it, the fire will become still more fierce.

Seeing the matters contained in this furnace are encompassed with fire on all sides, except in the fore-part opposite to the door of the fire-place, and as there are occasions which require that the force of the fire should be applied to this part also, an iron box, of the shape and size of the door, hath been contrived to answer that purpose. This box is filled with lighted coals, and applied immediately to the door-place, by which means the heat there is considerably augmented. This help may be made use of at the beginning of the operation, in order to accelerate it, and bring the heat sooner to the desired degree; or in case a very fierce heat be required; or at a time when the air being hot and moist will not make the fire burn with the necessary vigour.

The heat may be lessened by removing the iron box, and shutting the door of the fire-place quite close. It may be still further and gradually diminished, by taking off the conical funnel from the top; by shutting the door of the fire-place with one of its plates only, that which has the least, or that which has the greatest aperture in it; by taking off the pyramidal cover; by shutting the ash-hole door wholly or in part; and lastly, by setting the door of the fire-place wide open: but, in this last case, the cold air penetrates into the cavity of the Muffle, and refrigerates the cupels more than is almost ever necessary. If it be observed, during the operation, that the Muffle grows cold in any particular part, it is a sign there is a vacuity left by the coals in that place: in this case an iron wire must be thrust into the furnace, through the hole which is over the door of the fire-place, and the coals stirred

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therewith, so as to make them fall into their places and fill up the vacant interstices.

It is proper to observe that, besides what has been said concerning the ways of increasing the activity of the fire in the cupelling furnace, several other causes also may concur to procure to the matters contained in the Muffle a greater degree of heat: for example, the smaller the Muffle is, the wider and more numerous the holes in it are; the nearer to its bottom, or further end, the cupels are placed; the more will the matters therein contained be affected with heat.

Besides the operations to be performed by the cupel, this furnace is very useful and even necessary, for many chymical experiments; such, for instance, as those relating to sundry vitrifications and enamelling. As it is pretty low, the best way is to place it, when it is to be used, on a base of brick-work that may raise it to a level with the operator's hand.

A Lamp-furnace is exceeding useful for all operations that require only a moderate, but long continued, degree of heat. The furnace for working with a lamp-heat is very simple: it consists only of a hollow cylinder, from fifteen to eighteen inches high, and five or six in diameter, having at its bottom an aperture large enough for a lamp to be introduced and withdrawn with ease. The lamp must have three or four wicks, to the end that by lighting more or fewer of them a greater or less degree of heat may be produced. The body of the furnace must moreover have several small holes in it, in order to supply the flame of the lamp with air enough to keep it alive.

On the top of this furnace stands a basin five or six inches deep, which ought to fill the cavity of the cylinder exactly, and to be supported at its circumference by a rim which may entirely cover and close the furnace: the use of this basin is to contain

contain the sand through which the lamp heat is usually conveyed.

Besides this there must be a kind of cover or dome made of the same material with the furnace, and of the same diameter with the sand-bath, without any other opening than a hole, nearly circular, cut in its lower extremity. This dome is a sort of reverberatory, which serves to confine the heat and direct it towards the body of the retort; for it is used only when something is to be distilled in a vessel of this fashion; and then the hole at its bottom serves for a passage to the neck of the retort. This dome should have an ear or handle, for the conveniency of putting it on and taking it off with ease.

### *Of Lutes.*

CHYMICAL vessels, especially such as are made of glass, and the earthen vessels commonly called stone-ware, are very subject to break when exposed to sudden heat or cold; whence it comes that they often crack when they begin to heat, and also when being very hot they happen to be cooled, either by fresh coals thrown into the furnace, or by the access of cold air. There is no way to prevent the former of these accidents, but by taking the pains to warm your vessel very slowly, and by almost insensible degrees. The second may be avoided by coating the body of the vessels with a paste or lute, which being dried will defend it against the attacks of cold.

The fittest stuff for coating vessels is a composition of fat earth, Windsor-loam, fine sand, filings of iron, or powdered glass, and chopped cow's hair, mixed and made into a paste with water. This lute serves also to defend glass vessels against the violence of the fire, and to prevent their melting easily.

In almost all distillations it is of great consequence, as hath been said, that the neck of the distilling vessel be exactly joined with that of the re-

ceiver into which it is introduced, in order to prevent the vapours from escaping into the air and so being lost: and this junction is effected by means of a lute.

A few slips of paper applied round the neck of the vessels with common size will be sufficient to keep in such vapours as are aqueous, or not very spirituous.

If the vapours are more acrid, or more spirituous, recourse may be had to slips of bladder long steeped in water, which containing a sort of natural glue close the junctures of the vessels very well.

If it be required to confine vapours of a still more penetrating nature, it will be proper to employ a lute that quickly grows very hard; particularly a paste made with quick-lime and any sort of jelly, whether vegetable or animal; such as the white of an egg, stiff size, &c. This is an excellent lute and not easily penetrated. It is also used to stop any cracks or fractures that happen to glass vessels. But it is not capable of resisting the vapours of mineral acid spirits, especially when they are strong and smoking: for that purpose it is necessary to incorporate the other ingredients thoroughly with fat earth softened with water; and even then it frequently happens that this lute is penetrated by acid vapours, especially those of the spirit of salt, which of all others are confined with the greatest difficulty.

In such cases its place may be supplied with another, which is called Fat Lute, because it is actually worked up with fat liquors. This lute is composed of a very fine cretaceous earth, called tobacco-pipe clay, moistened with equal parts of the drying oil of lint-seed, and a varnish made of amber and gum copal. It must have the consistence of a stiff paste. When the joints of the vessels are closed up with this lute, they may, for greater security



curity, be covered over with slips of linen smeared with the lute made of quick-lime and the white of an egg.

Chymical vessels are liable to be broken in an operation by other causes besides the sudden application of heat or cold. It frequently happens that the vapours of the matters exposed to the action of fire rush out with such impetuosity, and are so elastic, that finding no passage through the lute with which the joints of the vessel are closed, they burst the vessels themselves, sometimes with explosion and danger to the operator.

To prevent this inconvenience, it is necessary that in every receiver there be a small hole, which being stopped only with a little lute may easily be opened and shut again as occasion requires. It serves for a vent-hole to let out the vapours, when the receiver begins to be too much crowded with them. Nothing but practice can teach the artist when it is requisite to open this vent. If he hits the proper time, the vapours commonly rush out with rapidity, and a considerable hissing noise; and the vent should be stopped again as soon as the hissing begins to grow faint. The lute employed to stop this small hole ought always to be kept so ductile, that by taking the figure of the hole exactly it may entirely stop it. Besides, if it should harden upon the glass, it would stick so fast that it would be very difficult to remove it without breaking the vessel. This danger is easily avoided by making use of the fat lute, which continues pliant for a long time, when it is not exposed to an excessive heat.

This way of stopping the vent-hole of the receiver has yet another advantage: for if the hole be of a proper width, as a line and half, or two lines, in diameter, then when the vapours are accumulated in too great a quantity, and begin to

make a great effort against the sides of the receiver, they push up the stopple, force it out, and make their way through the vent-hole: so that by this means the breaking of the vessels may always be certainly prevented. But great care must be taken that the vapours be not suffered to escape in this manner, except when absolute necessity requires it; for it is generally the very strongest and most subtile part of a liquor which is thus dissipated and lost.

Heat being the chief cause that puts the elasticity of the vapours in action, and prevents their condensing into a liquor, it is of great consequence in distillation that the receiver be kept as cool as possible. With this view a thick plank should be placed between the receiver and the body of the furnace, to intercept the heat of the latter, and prevent its reaching the former. As the vapours themselves rise very hot from the distilling vessel, they soon communicate their heat to the receiver, and especially to its upper part, against which they strike first. For this reason it is proper that linen cloths dipt in very cold water be laid over the receiver, and frequently shifted. - By this means the vapours will be considerably cooled, their elasticity weakened, and their condensation promoted.

By what hath been said in this first part, concerning the properties of the principal agents in Chymistry, the construction of the most necessary vessels and furnaces, and the manner of using them, we are sufficiently prepared for proceeding directly to the operations, without being obliged to make frequent and long stops, in order to give the necessary explanations on those heads.

Nevertheless we shall take every proper occasion to extend the theory here laid down, and to improve it by the addition of several particulars, which will find their places in our Treatise of Chymical Operations.

# E L E M E N T S

O F T H E

P R A C T I C E O F C H Y M I S T R Y ;

W H E R E I N

The Fundamental Operations are described,  
and illustrated by Observations on each  
Process.





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# E L E M E N T S

## OF THE

### PRACTICE OF CHYMISTRY.

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#### I N T R O D U C T I O N.

**A**S the Elements of the Theory of Chymistry, delivered in the former part of this work, were intended for the use of persons supposed to be altogether unacquainted with the art, they could not properly admit of any thing more than fundamental principles, so disposed as constantly to lead from the simple to the compound, from things known to things unknown: for which reason I could not therein observe the usual order of Chymical Decomposition, which is not susceptible of such a method. I therefore supposed all the analyses made, and bodies reduced to their simplest principles; to the end that, by observing the chief properties of those primary elements, we might be enabled to trace them through their several combinations, and to form some sort of judgment *à priori* of the qualities of such compounds as may result from their junctions.

But this latter part is of a different nature. It is a Practical Treatise, intended to contain the manner of performing the principal Operations of Chymistry; the operations which serve as standards for regulating all the rest, and which confirm the fundamental truths laid down in the Theory.

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As these operations consist almost wholly of analyses and decompositions, there can be no doubt concerning the order proper to be observed in giving an account of them: it evidently coincides with that of the analysis itself.

But as all bodies, which are the subjects of Chymical operations, are divided by nature into three classes or kingdoms, the mineral, the vegetable, and the animal, the analysis thereof may naturally be divided into three branches: some difference may also arise from the different order in which these three may be treated of.

As the reasons assigned for beginning with one kingdom rather than with another have never been thoroughly canvassed, and may perhaps seem equally good when viewed in a particular light, Chymical writers differ in their opinions on this point. For my part, without entering into a discussion of the motives which have determined others to follow a different order, I shall only produce the reasons that led me to begin with the mineral kingdom, to examine the vegetable in the second place, and to conclude with the animal.

First then, seeing vegetables draw their nourishment from minerals, and animals derive theirs from vegetables, the bodies which constitute these three kingdoms seem to be generated the one by the other, in a manner that determines their natural rank.

Secondly, this disposition procures us the advantage of tracing the principles, from their source in the mineral kingdom, down to the last combinations into which they are capable of entering, that is, into animal matters; and of observing the successive alterations they undergo in passing out of one kingdom into another.

Thirdly and lastly, I look upon the analysis of minerals to be the easiest of all; not only because they consist of fewer principles than vegetables and animals, but also because almost all of them are capable



ble of enduring the most violent action of fire, when that is necessary to their decomposition, without any considerable change or diminution of their principles, to which those of other substances are frequently liable.

Besides, I am not singular in this distribution of the three classes of bodies, which are the subjects of the chymical analysis: as it is the most natural, it has been adopted by several authors, or rather by most who have published Treatises of Chymistry. But there is something peculiarly my own in the manner wherein I have treated the analysis of each kingdom. In the mineral kingdom, for instance, will be found a considerable number of operations not to be met with in other Treatises of Chymistry; the authors having probably considered them as useless, or in some measure foreign, to the purpose of Elementary Books, and as constituting together a distinct art. I mean the processes for extracting saline and metallic substances from the minerals containing them.

Yet, if it be considered that salts, metals, and semi-metals are far from being produced by nature in a state of perfection, or in that degree of purity, which they are commonly supposed to have when they are first treated of in Books of Chymistry; but that, on the contrary, these substances are originally blended with each other, and adulterated with mixtures of heterogeneous matters, wherewith they form compound minerals; I imagine it will be allowed that the operations by which these minerals are decomposed, in order to extract the metals, semi-metals; and other simpler substances, especially as they are founded on the most curious properties of these substances, are so far from being useless or foreign to the purposes of an Elementary Treatise, that they are, on the contrary, absolutely necessary thereto.

After I had made these reflections, I could not help thinking that an analysis of minerals, which  
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should treat of saline and metallic substances, without taking any notice of the manner in which their matrices must be analysed, in order to extract them, would be no less defective, than a treatise of the analysis of vegetables, in which Oils, essential Salts, fixed and volatile Alkalis, should be amply treated of, without saying one word of the manner of analysing the plants from which these several substances are obtained. I therefore thought myself indispensably obliged to describe the manner of decomposing every ore or mineral, before I attempted to treat of the saline or metallic substance which it yields.

For example : as the Vitriolic Acid, with the consideration of which I begin my Mineral Analysis, is originally contained in Vitriol, Sulphur, and Alum ; and as these substances again derive their origin from the sulphureous and ferruginous Pyrites, the first operations I describe under this head are the processes for decomposing the Pyrites in order to extract its Vitriol, Sulphur, and Alum. I then proceed to the particular analysis of each of these substances, with a view to extract their Vitriolic Acid ; and afterwards deliver, in their order, the other operations usually performed on this Acid. Thus it appears that this saline substance occasions my describing the analyses of the Pyrites, Vitriol, Sulphur, and Alum. The whole of the Treatise on Minerals proceeds on the same plan.

The operations by which we decompose ores and minerals are of two sorts : those employed in working by the great, and those for trying in small the yield of any ore. These two manners of operating are sometimes a little different ; yet in the main they are the same, because they are founded on the same principles, and produce the same effects.

As my chief design was to describe the operations that may be conveniently performed in a laboratory, I have preferred the processes for small essays ; especially as they are usually performed with more

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care and accuracy than the operations in great works : and here I must acknowledge that I am obliged to M. Cramer's *Docimasia*, or Art of Assaying, for all the operations of this kind in my analysis of minerals. As M. Hellot's work on that subject did not appear till after I had finished this, M. Cramer's *Docimasia*, in which sound Theory is joined with accurate practice, was the best book of the kind I could at that time consult. I therefore preferred it to all others ; and as I have not quoted it in my analysis of minerals, because the quotations would have been too frequent, let what I say here serve for a general quotation. I have been careful to name, as often as occasion required, the other authors whose processes I have borrowed : it is a tribute justly due to those who have communicated their discoveries to the publick.

Though I have told the reader that in my analysis of minerals he will find the processes for extracting out of each the saline or metallic substances contained in it, yet he must not expect that this book will instruct him in all that it is necessary he should know to be able to determine, by an accurate assay, the contents of every mineral. My intention was not to compose a Treatise of Assaying ; and I have taken in no more than was absolutely necessary to make the analysis of minerals perfectly understood, and to render it as complete as it ought to be in an Elementary Treatise. I have therefore described only the principal operations relating thereto ; the operations which are fundamental, and which, as I said before, are to serve as standards for the rest, abstracted from such additional circumstances as are of consequence only to the Art of Assaying, properly so called.

Such therefore as are desirous of being fully instructed in that Art, must have recourse to those works which treat professedly of the subject ; and parti-



particularly to that published by M. Hellot: a performance most esteemed by such as are best skilled in Chymistry, and rendered so complete by the numerous and valuable observations and discoveries of the Author, that nothing better of the kind can be wished for. I thought it proper to give these notices in relation to my analysis of minerals; and shall now proceed to shew the plan of my analyses of vegetables and of animals.

Seeing all vegetable matters are susceptible of fermentation, and when analysed after fermentation, yield principles different from those we obtain from them before they are fermented, I have divided them into two classes; the former including vegetables in their natural state, before they have undergone fermentation; and the latter those only which have been fermented. This analysis opens with the processes by which we extract from vegetables all the principles they will yield without the help of fire; and then follow the operations for decomposing plants by degrees of heat, from the gentlest to the most violent, both in close vessels and in the open air.

I have not made the same division in the animal kingdom, because the substances that compose it are susceptible only of the last degree of fermentation, or putrefaction; and moreover the principles they yield, whether putrefied or unputrefied, are the very same, and differ only with regard to their proportions, and the order in which they are extricated during the analysis.

I begin this analysis with an examination of the milk of animals that feed wholly on vegetables; because though this substance be elaborated in the body of the animal, and by that means brought nearer to the nature of animal matters, yet it still retains a great similitude to the vegetables from which it derives its origin, and is a sort of  
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intermediate substance between the vegetable and animal. Then I proceed to the analysis of animal matters properly so called, those which actually make a part of the animal body. I next examine the excrementitious substances, that are thrown out of the animal body as superfluous and useless. And then I conclude this latter part with operations on the Volatile Alkali; a saline substance of principal consideration in the decomposition of animal matters.

Though, in the general view here given of the order observed in this Treatise of Practical Chymistry, I have mentioned only such processes as serve for analysing bodies, yet I have also inserted some other operations of different kinds. The book would be very defective if it contained no more: for the design of Chymistry is not only to analyse the mixts produced by nature, in order to obtain the simplest substances of which they are composed, but moreover to discover by sundry experiments the properties of those elementary principles, and to recombine them in various manners, either with each other, or with different bodies, so as to reproduce the original mixts with all their properties, or even form new compounds which never existed in nature. In this book therefore the reader will find processes for combining and recompounding, as well as for resolving and decomposing bodies. I have placed them next to the processes for decomposition, taking all possible care not to interrupt their order, or break the connection between them.

# E L E M E N T S

OF THE

## PRACTICE OF CHYMISTRY.

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### P A R T I.

### OF MINERALS.

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#### SECTION I.

*Operations performed on Saline Mineral Substances.*

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#### CHAP. I.

*Of the VITRIOLIC ACID.*

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#### PROCESS I.

*To extract Vitriol from the Pyrites.*

**T**AKE any quantity you please of Iron-Pyrites; leave them for some time exposed to the air; they will crack, split, lose their brightness, and fall into powder. Put this powder into a glass cucurbit, and pour upon it twice its weight of hot water; stir the whole with a stick, and the liquor will grow turbid. Pour it, while it is yet warm, into a glass funnel lined with brown filtering paper; and having placed your funnel over another glass cucurbit, let the liquor drain into it. Pour more



more hot water on the powdered Pyrites, filter as before, and so go on, every time lessening the quantity of water, till that which comes off the Pyrites appears to have no astringent vitriolic taste.

Put all these waters together into a glass vessel that widens upwards; set it on a sand-bath, and heat the liquor till a considerable smoke arises; but take care not to make it boil. Continue the same degree of fire till the surface of the liquor begins to look dim, as if some dust had fallen into it; then cease evaporating, and remove the vessel into a cool place: in the space of four-and-twenty hours will be formed therein a quantity of crystals, of a green colour and a rhomboidal figure: these are Vitriol of Mars, or Copperas. Decant the remaining liquor; add thereto twice its weight of water; filter, evaporate, and crystallize as before; repeat these operations till the liquor will yield no more crystals, and keep by themselves the crystals obtained at each crystallization.

### OBSERVATIONS.

THE Pyrites are minerals which, by their weight and shining colours, frequently impose on such as are not well acquainted with ores. At first sight they may be taken for very rich ones; and yet they consist only of a small quantity of metal combined with much sulphur or arsenic, and sometimes with both.

They strike fire with a steel as flints do, and emit a sulphureous smell: so that they may be known by this extemporaneous proof. The metal most commonly and most abundantly found in the Pyrites is iron; the quantity whereof sometimes equals, or even exceeds, that of the sulphur. Besides metallic and sulphureous matters, the Pyrites contain also some unmetallic earth.

There are several sorts of Pyrites: some of them contain only iron and arsenic. They have not all the property of efflorescing spontaneously in the air,

and turning into vitriol: none do so but such as consist only of iron and sulphur, or at least contain but a very small portion of copper, or of arsenic: and even amongst those that are composed of iron and sulphur alone, there are some that will continue for years together exposed to the air without shooting, and indeed without suffering the least sensible alteration.

The efflorescence of the Iron-Pyrites, and the changes they undergo, are phenomena well worth our notice. They depend on the singular property which iron possesses of decomposing sulphur by the help of moisture. If very fine iron-filings be accurately mingled with flowers of sulphur, this mixture, being moistened with water, grows very hot, swells up, emits sulphureous vapours, and even takes fire: what remains is found converted into Vitriol of Mars. On this occasion, therefore, the sulphur is decomposed; its inflammable part is dissipated or consumed; its acid combines with the iron, and a Vitriol arises from that conjunction.

This is the very case with the Pyrites that consist only of iron and sulphur; yet some of them, as we said before, do not effloresce spontaneously and turn to Vitriol. The reason probably is that, in such minerals, the particles of iron and sulphur are not intimately mixed together, but separated by some earthy particles.

In order to procure Vitriol from Pyrites of this kind, they must be for some time exposed to the action of fire, which by consuming part of their sulphur, and rendering their texture less compact, makes way for the air and moisture, to which they must be afterwards exposed, to penetrate their substance, and produce in them the changes with which those others are affected that germinate spontaneously.

The Pyrites which contain copper and arsenic, and for that reason do not effloresce, must likewise undergo

undergo the action of fire; which besides the effects it produces on Pyrites that consist of iron and sulphur only, dissipates also the greatest part of the arsenic. These Pyrites being first roasted, and then exposed to the air for a year or two, do also yield Vitriol; but then it is not a pure Vitriol of Iron, but is combined with a portion of blue Vitriol, the basis of which is Copper.

Sometimes also there is Alum in the vitriolic waters drawn off the Pyrites. It was on account of this mixture of different salts that we recommended the keeping apart the crystals obtained from each different crystallization: for by this means they may be examined separately, and the species to which they belong discovered.

When Vitriol of iron is adulterated with a mixture of the Vitriol of copper only, it is easy to purify it and bring it to be entirely martial, by dissolving it in water, and setting plates of iron in the solution: for iron having a greater affinity than copper with the vitriolic acid, separates the latter from it, and assuming its place produces a pure Vitriol of Mars.

In large works for extracting Vitriol from the Pyrites they proceed thus. They collect a great quantity of Pyrites on a piece of ground exposed to the air, and pile them up in heaps of about three feet high. There they leave them exposed to the action of the air, sun, and rain, for three years together; taking care to turn them every six months, in order to facilitate the efflorescence of those which at first lay undermost. The rain-water which has washed those Pyrites is conveyed by proper channels into a cistern; and when a sufficient quantity thereof is gathered, they evaporate it to a pellicle in large leaden boilers, having first put into it a quantity of iron, some part of which is dissolved by the liquor, because it contains a vitriolic acid that is not fully saturated therewith. When it



is sufficiently evaporated, they draw it off into large leaden or wooden coolers, and there leave it to shoot into crystals. In these last vessels several sticks are placed, crossing each other in all manner of directions, in order to multiply the surfaces on which the crystals may fasten.

The Pyrites are not the only minerals from which Vitriol may be procured. All the ores of iron and copper that contain sulphur may also be made to yield green or blue Vitriol, according to the nature of each; by torrefying them, and leaving them long exposed to the air: but this use is seldom made of them, as there is more profit to be got by extracting the metals they contain. Besides, it is easier to obtain Vitriol from Pyrites, than from those other mineral substances.

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## PROCESS II.

*To extract Sulphur from the Pyrites, and other sulphureous Minerals.*

**R**EDUCE to a coarse powder any quantity of yellow Pyrites, or other Mineral containing Sulphur. Put this powder into an earthen or glass retort, having a long wide neck, and so large a body that the matter may fill but two-thirds of it. Set the retort in a sand-bath fixed over a reverberating furnace: fit it to a receiver half full of water, and so placed that the nose of the retort may be about an inch under the water: give a gradual fire, taking care you do not make it so strong as to melt the matter. Keep the retort moderately red for one hour, or an hour and half, and then let the vessels cool.

Almost all the Sulphur separated by this operation from its matrix will be found at the extremity of the neck of the retort, being fixed there by  
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the water. You may get it out either by melting it with such a gentle heat as will not set it on fire; or by breaking the neck of the retort.

### OBSERVATIONS.

OF all minerals the Pyrites contain the most Sulphur; those especially which have the colour of fine brass, a regular form, such as round, cubical, hexagonal, and being broken present a number of shining needles, all radiating, as it were, from a center.

A very moderate heat is sufficient to separate the Sulphur they contain. We directed that the retort employed should have a long and wide neck, with a view to procure a free passage for the Sulphur: the water set in the receiver detains the Sulphur, fixes it, and prevents it from flying off; so that it is unnecessary to close the joints of the vessels. But it is proper to take notice that when ever you use an apparatus for distilling, which requires the beak of the retort to be under water, it is of very great consequence that the fire be constantly so regulated that the retort may not cool in the least; for in that case, as the rarefied air contained therein would be condensed, the water in the receiver would rise into the retort and break it.

If in distilling Sulphur, according to the present process, the matter contained in the retort should happen to melt, the operation would be thereby considerably protracted, and it would require a great deal more time to extract all the Sulphur; because all evaporation is from the surface only, and the matter, while it remains in a coarse powder, presents a much more extensive surface than when it is melted.

This remark holds with regard to all other distillations. Any quantity of liquor, set to distil in its fluid state, will take much more time to rise in vapours, and pass from the retort into the receiver,

than if it be incorporated with some solid body reduced to minute parts, so that the whole shall make a moist powder; and this though the very same degree of fire be applied in both cases.

If the matter from which it is proposed to extract Sulphur be such as will melt with the degree of fire necessary to this operation; that is, with a heat which will make the retort but faintly red, it must be mixed with some substance that is not so fusible. Very pure coarse sand, or clean gravel, may be used with success: but absorbent earths are altogether improper for this purpose, because they will unite with the Sulphur.

The sulphureous minerals which are most apt to fuse are the cupreous Pyrites, or yellow copper ores: common lead ores are also very fusible.

The Pyrites are by this operation deprived of almost all the Sulphur they contain; and consequently little is left behind, but the particles of iron and copper, together with a portion of unmetallic earth, which we shall shew how to separate from these metals, when we come to treat of them. I say that by this operation the Pyrites are deprived of almost all, and not entirely of all their Sulphur; because, this separation being made in close vessels only, there always remains a certain quantity of Sulphur, which adheres so obstinately to the metals, that it would be almost impossible to get it all out, even though a much stronger fire than that directed in the process were applied for this purpose, and though choice had been, as it ought to be, made of such Pyrites, or other sulphureous Minerals, as part most easily with their Sulphur. Nothing but a very strong fire in the open air is capable of carrying it wholly off, or consuming it entirely.

In several places are found great quantities of native Sulphur. The Volcanos abound with it, and people gather it at the foot of those burning mountains.



mountains. Several springs of mineral waters also yield Sulphur, and it is sometimes found sublimed to the vaulted roofs of certain wells, and among others in one at Aix-la-Chapelle.

The Germans and Italians have large works, for extracting Sulphur in quantities out of Pyrites, and other minerals which abound therewith. The process they work by is the same with that here delivered; but with this difference only, that Sulphur being but of small value they do not use so many precautions. They content themselves with putting the sulphureous minerals into large crucibles, or rather earthen cucurbits, which they place in the furnace in such a manner that, when the sulphureous part melts, it runs into vessels filled with water, and is thereby fixed.

The Sulphur obtained, either by distillation or by simple fusion, is not always pure.

When it is obtained by distillation, if the matters from which you extract it contain moreover some other minerals of nearly the same volatility, such, for instance, as Arsenic, or Mercury, these minerals will come over with it. This is easily perceived: for pure sublimed Sulphur is always of a beautiful yellow, inclining to a lemon colour. If it look red, or have a reddish cast, it is a sign that some Arsenic hath arisen along with it.

Mercury sublimed with Sulphur likewise gives it a red colour; but Sulphur is very seldom adulterated with this metallic substance: for Arsenic is frequently found combined with the Pyrites, and other sulphureous minerals: whereon the contrary we very rarely meet with any Mercury in them.

But if Mercury should happen to rise with the Sulphur in distillation, it may be discovered by examining the sublimate; which, in that case, will have the properties of Cinabar: on being broken its inside will appear to consist of needles adhering laterally

terally to each other; its weight will be very considerable; and lastly, the great heat of the place where it is collected will furnish another mark to know it by; for as Cinabar is less volatile than Arsenic or Sulphur, it fastens on places too hot for either Sulphur or Arsenic to bear.

Sulphur may also be adulterated with such fixed matters, either metallic or earthy, as it may have carried up along with it in the distillation, or as may have been sublimed by the Arsenic, which has a still greater power than Sulphur to volatilize fixed bodies.

If you desire to free the Sulphur from most of these heterogeneous matters, it must be put into an earthen cucurbit, and set in a sand-bath. To the cucurbit must be fitted one or more aludels, and such a degree of heat applied as shall but just melt the Sulphur; which is much less than that necessary to separate the Sulphur from its matrix. As soon as the Sulphur is melted it will sublime in lemon-coloured flowers, that will stick to the insides of the aludels.

When nothing more appears to rise with this degree of heat, the vessels must be suffered to cool. At the bottom of the cucurbit will be found a sulphureous mass, containing the greatest part of the adventitious matters that were mixed with the Sulphur, and more or less red or dark-coloured, according to the nature of those matters.

When we come to treat of Arsenic and Mercury, we shall give the methods of separating Sulphur entirely from those metallic substances.

### PROCESS III.

*To extract Alum from aluminous Minerals.*

**T**AKE such materials as are known or suspected to contain Alum. Expose them to the air, that they may effloresce. If they remain there a year

year without any sensible change, calcine them, and then leave them exposed to the air, till a bit thereof being put on the tongue imparts an astringent aluminous taste.

When your matters are thus prepared, put them into a leaden or glass vessel; pour upon them thrice their weight of hot water; boil the liquor; filter it; and repeat these operations till the earth be soedulcorated that the water which comes off it hath no taste. Mix all these solutions together, and let them stand four-and-twenty hours, that the gross and earthy parts may settle to the bottom; or else filter the liquor: then evaporate till it will bear a new-laid egg. Now let it cool, and stand quiet four-and-twenty hours: in that time some crystals will shoot, which are most commonly vitriolic; for Alum is rarely obtained by the first crystallization. Remove these vitriolic crystals: if any crystals of Alum be found amongst them, these must be dissolved anew, and set to crystallize a second time in order to their purification; because they partake of the nature as well as of the colour of vitriol. By this method extract all the Alum that the liquor will yield.

If you get no crystals of Alum by this means, boil your liquor again, and add to it a twentieth part of its weight of a strong alkaline lixivium, or a third part of its weight of putrefied urine, or a small quantity of quick-lime. Experience and repeated trials must teach you which of these three substances is to be preferred, according to the particular nature of the mineral on which you are to operate. Keep your liquor boiling, and if there be any Alum in it, there will appear a white precipitate: in that case let it cool and settle. When the white precipitate is entirely fallen, decant the clear, and leave the crystals of Alum to shoot at leisure,



till the liquor will yield no more: it will then be exceeding thick.

### OBSERVATIONS.

ALUM is obtained from several sorts of Minerals. In some parts of Italy, and in sundry other places, it effloresces naturally on the surface of the earth. There it is swept together with brooms, and thrown into pits full of water. This water is impregnated therewith till it can dissolve no more. Then it is filtered, and set to evaporate in large leaden vessels; and when it is sufficiently evaporated, and ready to shoot into crystals, it is drawn off into wooden coolers, and there left for the salt to crystallize.

In aluminous soils there are often found springs strongly impregnated with Alum; so that to obtain it the water need only be evaporated.

In the country about Rome there is a very hard stone, which is hewn out of the quarry just like other stones for building: this stone yields a great deal of Alum. In order to extract it, the stones are calcined for twelve or fourteen hours; after which they are exposed to the air in heaps, and carefully watered three or four times a day for forty days together. In that time they begin to effloresce, and to throw out a reddish matter on their surface. Then they are boiled in water, which dissolves all the Alum they contain, and being duly evaporated gives it back in crystals. This is the Alum called *Roman Alum*.

Several sorts of Pyrites also yield a great deal of Alum. The English have a stone of this kind, which in colour is very like a slate. This stone contains much Sulphur, which they get rid of by roasting it. After this they steep the calcined stone in water, which dissolves the Alum it contains, and to this solution they add a certain quantity of a lye made of the ashes of sea-weeds.

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The Swedes have a Pyrites of a bright, golden colour, variegated with silver spots, from which they procure Sulphur, Vitriol, and Alum. They separate from it the Sulphur and the Vitriol by the methods above prescribed. When the liquor which hath yielded Vitriol is become thick, and no more vitriolic crystals shoot in it, they add an eighth part of its weight of putrefied urine, mixed with a lye made of the ashes of green wood. Upon this there appears and falls to the bottom a copious red sediment. They decant the liquor from this precipitate, and when it is duly evaporated find it shoot into beautiful crystals of Alum.

What hath been said, concerning the several matrices from which Alum is obtained, sufficiently shews that it is seldom solitary in the waters with which aluminous subjects have been lixiviated. It is almost always accompanied with a certain quantity of Vitriol, or other saline mineral matters, which obstruct its crystallization, and prevent its being pure. 'Tis with a view to free it from these matters, that the waters impregnated with Alum are mixed with a certain quantity of the lye of some fixed Alkali, or with putrefied urine, which contains much volatile Alkali. These Alkalis have the property of decomposing all the Neutral salts which have for their basis either an absorbent earth or a metallic substance; and such as have a metallic substance for their basis more readily than those whose basis is an earth. Consequently, if they are mixed with a liquor in which both these sorts of salts are dissolved, they must decompose that sort whose basis is metallic sooner than the other whose basis is an earth. This is what comes to pass in a solution of Alum and Vitriol. The metallic part of the latter is separated from its acid by the Alkalis when mixed with that solution; and 'tis this metallic part, which is generally iron, that appears in the form of a reddish precipitate, as above-mentioned.

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But because Alkalis decompose also those Neutral salts which have an earth for their basis, care must be taken that too much thereof be not added; else what you put in, more than is necessary to decompose the vitriolic salts in your liquor, will attack the Alum, and decompose it likewise.

The Alkali made use of to promote the crystallization of the Alum joins with the Vitriolic Acid, which had dissolved the substances now precipitated, and therewith forms different Neutral salts according to its particular nature. If the Alkali be a lixivium of common wood-ashes, the Neutral salt will be a vitriolated Tartar; if a lixivium of the ashes of a maritime plant like Soda, the Neutral salt will be a Glauber's salt; if putrefied urine, the Neutral salt will be a vitriolic Ammoniacal salt. Some of these salts incorporate with the Alum, which in large works crystallizes in vast lumps: and hence it comes that some sorts of Alum when mixed with a fixed Alkali smell like a volatile Alkali.

The crystals of Alum are octaedra, that is, they are solids with eight sides. These octaedra solids are triangular pyramids, having their angles cut away, so that four of their surfaces are hexagons, and the other four triangles.

Sulphur, Vitriol, and Alum are the three principal subjects in which we certainly know that the universal or Vitriolic Acid particularly resides, and from which we extract it when we want to have it pure. For this reason we thought it proper, before we treated of the extraction of this Acid, to shew the method of separating those matters themselves from the other minerals out of which we obtain them.

Moreover, all the other matrices, in which the Vitriolic Acid is most commonly lodged, may be referred to one or other of the matters which serve as bases to these three minerals.



To Sulphur we may refer all combinations of the Vitriolic Acid with an inflammable matter; but we must take care not to confound Sulphur with those Bitumens in which the Vitriolic Acid may be found: for the basis of those bitumens is a real Oil; whereas the basis of Sulphur is the pure Phlogiston. Yet as Oils themselves contain the Phlogiston, which in union with the Vitriolic Acid forms a true Sulphur, it follows that such bitumens may in a certain respect be classed with Sulphur.

The same is to be said of Vitriol. The name is usually given to such combinations only as are formed of the Vitriolic Acid with Iron or Copper, which make the green and blue Vitriol; and to a third species of Vitriol, which is white, and has Zinc for its basis: but as the Vitriolic Acid may, by particular combinations, be united with many other metallic substances, all such Metallic Salts must be referred to the class of Vitriols.

The same may also be said of Alum, which is no other than a combination of the Vitriolic Acid with a particular kind of absorbent earth; so that all combinations of this Acid with any earth whatever may be placed in the same class.

This last class of mixts is the most extensive of all that contain the Vitriolic Acid; because there are a vast many earths, all differing from one another, with which that Acid may be united. Alum properly so called, the Gypsums, Talcs, Selenites, Boles, and all the other compounds of this kind, differ from each other only in their particular earths.

The different properties of these earthy salts depend on the nature of their bases. Those which are of the aluminous kind, retain much water in crystallizing, which makes them very soluble in water, and gives them the property of acquiring readily the aqueous fluor when exposed to the fire. Those which are of the nature of the Selenites admit but very little water in their crystals, and consequently  
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are almost insoluble in water; nor does the fire give them an aqueous fluor. Lastly, the Gypsums and Talcs are still more destitute of these properties. The natures of the earths in these several compounds are hitherto but very imperfectly known, and may give the Chymists occasion for enquiries equally curious and useful.

The Vitriolic Acid is sometimes found complicated with a fixed alkaline basis. This is almost always the Alkali of Sea-salt; so that the compound is a Glauber's Salt. Some mineral waters are impregnated therewith; which happens when these waters contain Vitriol or Alum, together with Sea-salt.

From the principles laid down, in our Elements of the Theory, it appears that the Vitriolic Acid hath not so great an affinity with earthy and metallic substances as with fixed Alkalis; and also that it is stronger than the Marine Acid, and hath a greater affinity with fixed Alkalis. This being allowed, the generation of native Glauber's Salts is easily accounted for. The Acid of aluminous or Vitriolic salts quits the earth or the metal with which it was combined, and expelling the Acid of sea-salt unites with its basis. Warmth greatly promotes these decompositions.

If the common fossil salt, usually called *Sal Gem*, or any other kind of Sea-salt, should happen to be near a Volcano, when it discharges flaming Sulphur, as is frequently the case, and if this Sulphur should run among the Sea-salt, a Glauber's Salt would instantly be formed in that place; because when Sulphur burns, its Acid is separated and set at liberty.

Lastly, if aluminous or vitriolic matters, or burning Sulphur, should meet with the ashes of plants or trees consumed by fire, a vitriolated Tartar would be formed, because these ashes contain a fixed Alkali of the same nature with that of Tartar.

The Vitriolic Acid when combined with an earthy basis adheres strongly thereto; so that the force of  
fire

fire is able to expel very little or none of it. There is no way of separating it from such a basis, but by presenting to it an Alkaline Salt, with which it will unite: nor is it ever extracted from such matters when it is required pure. It does not adhere so firmly to metallic substances; but is separated from them by the force of fire: so that it may be obtained from the several sorts of Vitriol. It is usually drawn from Green Vitriol; that being the commonest sort.

As to Sulphur, the Phlogiston which is its basis being the substance wherewith the Vitriolic Acid hath the greatest affinity, it would be altogether impossible to decompose it, and to separate its Acid, if it were not inflammable; but by burning it the Phlogiston is destroyed, and leaves the Acid at liberty. By this means therefore it may be separated. We shall now give the processes for extracting the Acid from Vitriol and Sulphur.

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#### P R O C E S S IV.

*To extract the Vitriolic Acid from Green Vitriol.*

**T**AKE any quantity of Green Vitriol: put it in an unglazed earthen vessel, and heat it gradually. Vapours will soon begin to rise. Encrease the fire a little, and it will liquefy by means of the water contained in it, and acquire what we called an *aqueous* fluor. Continue the calcination, and it will become less and less fluid, grow thick, and turn of a greyish colour. Now raise your fire, and keep it up till the salt recovers its solidity, acquire an orange colour, and begin to grow red where it immediately touches the sides of the vessel. Then take it out, and reduce it to powder.

Put the Vitriol thus calcined and pulverized into a good earthen retort, of which one-half at least



must remain empty. Set the retort in a reverberatory furnace: fit thereto a large glass receiver, and, having luted the joint well, give fire by degrees. You will soon see white clouds rise into the receiver, which will render it opaque, and heat it. Continue the same degree of fire till these clouds disappear: they will be succeeded by a liquor which will trickle down the sides of the receiver in veins. Still keep up the fire to the same degree as long as these veins appear. When they begin to abate, encrease the fire, and push it to the utmost extremity: upon this, there will come over a black, thick liquor: it will even be found congealed, and prove the Icy Oil of Vitriol, if care hath been taken to change the receiver, keep the vessels perfectly close, and give a sufficient degree of heat. Proceed thus till nothing more comes over, or at least very little. Let the vessels cool, unlute them, pour the contents of the receiver into a bottle, and seal it hermetically.

### OBSERVATIONS.

GREEN Vitriol retains much water in crystallizing; and in order to free it from that superfluous phlegm, it must be calcined before you distil it. Without this precaution the operation will be exceedingly protracted, and a great deal of time wasted in distilling such a quantity of water; which will moreover greatly weaken the Acid by commixing with it, unless care be taken to change the recipient as soon as the water is all come over.

But there is also another advantage in calcining the Vitriol before you put it into the retort: for otherwise this salt would melt on the first application of heat, and run into a mass; which would prove a great hindrance to its distillation. This inconvenience is avoided by a previous calcination, in consequence whereof the Vitriol is easily reduced to a powder which never becomes fluid.

Vitrio

Vitriol calcined as directed in the process grows so hard, and adheres so firmly to the vessel in which the calcination is performed, that it requires no small pains to separate and pulverize it. Care must be taken to put it into the retort as soon as it is pulverized, and to stop that vessel very close if you do not begin the distillation immediately: for otherwise it will naturally attract from the air almost all the moisture it hath lost.

The Acid which Vitriol yields by distillation is sulphureous; probably because it still retains some of the Phlogiston, with which it was united when under the form of sulphur in the Pyrites; or else hath laid hold on a portion of that belonging to the iron which served for its basis in Vitriol. But this sulphureous part is volatile, and flies off in time.

This decomposition of Vitriol in close vessels is difficult and laborious process. To carry the operation to its utmost perfection requires a fire of extreme violence, kept up without intermission during four or five days; such in short as few vessels are able to bear. Of course this operation is seldom performed in laboratories. The French Chymists fetch their Oil of Vitriol from Holland, where it is extracted from Vitriol in large quantities, by means of furnaces erected for the purpose, in which many retorts are employed at once.

In the Memoirs of the Academy of Sciences M. Lellot hath given us the most material circumstances of a very fine experiment of this kind, in which he pushed the distillation of Green Vitriol to the utmost. Into a German retort \* he put six pounds of Green English Vitriol calcined to redness, which he exposed to a fire of the extremest violence, constantly kept up during four days and four nights. At the expiration of that time he

\* They are much the best, and bear a very fierce heat.

found in the vessels employed as receivers an Icy Oil of Vitriol, which was altogether in a crystal-line form and black. The precautions necessary to make this experiment succeed he represents in the following terms.

“ The success of this operation, which produces  
 “ an Oil of Vitriol perfectly Icy and without any  
 “ liquor, depends on the care taken to prevent the  
 “ acid vapours, driven by the fire out of Vitriol  
 “ calcined to redness, from having any communi-  
 “ cation with the external air while they are distil-  
 “ ling: for otherwise they will attract from it a  
 “ moisture which will keep them fluid in the re-  
 “ ceiver. The receiver must be at such a distance  
 “ from the furnace that it may remain cool enough  
 “ for the vapours to condense in it. There must  
 “ also be sufficient room for those vapours to cir-  
 “ culate in, and to prevent the sulphureous explo-  
 “ sions, which are every now and then discharged  
 “ out of the retort, from bursting the vessels: for  
 “ though the previous calcination of the Vitriol  
 “ hath carried off the most volatile, yet there still  
 “ remains enough of the inflammable principle,  
 “ even in the iron itself, to form a Sulphur with  
 “ the Acid as it is extricated, or at least a mixt  
 “ that would be as apt to take fire as common Sul-  
 “ phur, if it were not over-dosed with the Acid.  
 “ As the best means of gaining these ends Mr  
 “ Hellot contrived to adapt to the neck of his  
 “ retort a receiver with two necks, the lowermost  
 “ of which was inserted into a large ballon. Re-  
 “ ceivers applied to each other in this manner are  
 “ called Adopters.

“ It is no easy matter to get this Icy Oil o  
 “ of the ballon: for as soon as the air touches  
 “ such a thick cloud of sulphureous fumes arise  
 “ that it is absolutely necessary to place the ve  
 “ on some shelf over head, because a man can  
 “ sta



“ stand expos'd thereto for a single minute with-  
 “ out being suffocated.”

This Icy Acid must be shut up with all possible expedition in a crystal bottle accurately clos'd with a glass stopple, which should be ground with emery in its neck so as to fit it exactly: for it attracts moisture so powerfully, that, unless exceeding great care be taken to prevent all communication with the external air, it will soon dissolve into a fluid.

“ The Icy Oil is black; because the acid vapours  
 “ carry over with them something of a greasy  
 “ matter, from which Vitriol is seldom free, and  
 “ which always appears, after repeated solutions  
 “ and crystallizations of this Salt, in the mother-  
 “ water which will shoot no more. Now the  
 “ smallest portion of inflammable matter presently  
 “ blackens the most highly rectified Oil of Vitriol,  
 “ which is perfectly clear.

“ The Vitriolic Acid, when forced over by a  
 “ violent heat, carries along with it some ferrugi-  
 “ nous particles also, that want nothing but to be  
 “ united with a Phlogiston to become true iron.  
 “ They are easily discovered, either in the common  
 “ black Oil of Vitriol, or in the blackish crystals  
 “ of the Icy Oil, by only dissolving them in a large  
 “ quantity of distilled water: for after seven or  
 “ eight days digestion a light powder or downy  
 “ sediment precipitates, which being calcined in a  
 “ violent fire is partly attracted by the magnet;  
 “ and being again calcined with bees-wax becomes  
 “ almost entirely iron.”

The *Caput mortuum* of this distillation of Vitriol is the ferruginous earth of this Salt, and is called *Colcothar*. When this Colcothar hath undergone a violent fire, as in the experiment now related, scarce any Acid remains therein. Out of six pounds of Vitriol that M. Hellot used, he could recover no more, by lixiviating what was left in the retort,

than two ounces of a Vitriolic Salt ; and even that was very earthy.

If Vitriol be exposed to a fire neither so violent nor so long continued, its Colcothar will yield a greater quantity of Vitriol that hath not been decomposed. A white crystalline salt is also obtained from it, and called *Salt of Colcothar* ; which is no other than the small portion of Alum usually contained in Vitriol, and not so easily decomposed by the action of fire.

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### PROCESS V.

*To decompose Sulphur, and extract its Acid, by burning it.*

**T**AKE any quantity of the purest Sulphur : fill therewith a crucible or other earthen dish : heat it till it melts : then set in on fire ; and when its whole surface is lighted place it under a large glass head, taking care that the flame of the Sulphur do not touch either its sides or bottom ; that the air have free access, in order to make the Sulphur burn clear ; and that the head incline a little toward the side on which its beak is, that as the vapours condense therein the liquor may run off with ease. To the beak of this vessel fit a receiver : the fumes of the lighted Sulphur will be condensed, and gather into drops in the head, out of which they will run into the receiver. There, when the Sulphur has done burning, you will find an Acid liquor, which is the Spirit of Sulphur.

### OBSERVATIONS.

IN the burning of Sulphur, the Phlogiston which serves for its basis is dissipated, and separated from the Acid which is left at liberty. The acid fumes which rise from the lighted sulphur strike against the inside

inside of the head placed over it, are there condensed, and appear in the form of a liquor. But as Sulphur, like all other inflammable bodies, Nitre excepted, will not burn in close vessels, it is necessary that the air be freely admitted here; which occasions the loss of a great deal of the Acid of the Sulphur, as is evident from the pungent suffocating smell perceived in the laboratory during the operation.

This Acid, while combined with the Phlogiston, is incapable of contracting any union with water; but when alone is very apt to mix therewith: it is even proper to put some in its way, that it may incorporate therewith as soon as it is discharged from the Sulphur; for it is then very free from phlegm, very volatile, and consequently very little disposed to condense into a liquor, but on the contrary very apt to fly off in vapours. The water, which it imbibes with a kind of avidity, fixes and detains it; so that by this means a much greater quantity thereof is obtained from Sulphur, than if it were distilled without this precaution.

It is proper therefore now and then to introduce a dish full of hot water under the head which receives the fumes of the Sulphur. The vapours that exhale from the water bedew the inside of the head, and procure the advantage we are speaking of.

The same thing may be effected several other ways: thus, the crucible containing the Sulphur may be set on a foot placed in an earthen dish with some water in it; which however must not rise above the foot; for if it should reach the crucible, it might cool and fix the sulphur. The dish thus prepared must be placed on a sand-bath hot enough to make the water smoke continually; and over all is to be placed the head as directed in the process.

The size and form of the vessel which immediately receives the sulphureous fumes may also



contribute to increase the quantity of the Acid Spirit. A very large vessel, with a hole at bottom no wider than is just sufficient to admit the vapours, is the properest for this operation.

After the Sulphur has burnt for some time, it often happens that a sort of skin or crust forms on its surface, which is not inflammable, but gradually lessens the quantity and vigour of the flame as it increases in thickness, and at last puts it quite out. This crust proceeds from the impurities, and heterogeneous uninflammable particles contained in the sulphur. Care must be taken to remove it with an iron wire as fast as it forms.

Two quantities of Sulphur may also be kept in two crucibles, and heated alternately. That in which the Sulphur is hot and melted may be substituted for the other in which the Sulphur is grown cold and fixed; because cold Sulphur does not burn well.

The Spirit of Sulphur is at first pungent and volatile, because it still retains a small portion of the Phlogiston: but that sulphureous part flies off, especially if the bottle in which the Spirit is kept be left for some time unstopped.

The Acid obtained from Sulphur appears by all chymical proofs perfectly like that obtained from Vitriol: they differ in this only that the former is the purest; for the Acid obtained from Vitriol carries over with it some metallic parts, as we observed before, which can never happen to that obtained from Sulphur.

If linen rags dipped in a solution of Fixed Alkali be exposed to the fumes of burning brimstone, the Spirit of Sulphur joins with the Alkali, and therewith forms a Vitriolated Tartar. This Salt is known to be formed when the rags grow stiff, and appear spangled with a vast many glittering points  
which

which are nothing but little crystals of the Salt we are speaking of.

When the Sulphur burns very gently and slowly the Spirit that exhales from it is so much the more sulphureous and volatile: and hence the Salt formed by the combination of this Spirit with the Alkali exposed to it in linen rags, as in the above-mentioned experiment, is not at first a Vitriolated Tartar; but a Neutral Salt of a particular kind, which is capable of being decomposed by any other Mineral Acid, the sulphureous Acid having less affinity than any of the rest with Alkalis. Nevertheless this Salt becomes in time a true Vitriolated Tartar, because the sulphureous part which weakened its Acid easily quits it and flies off.

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## P R O C E S S VI.

*To concentrate the vitriolic Acid.*

**T**AKE the Vitriolic Acid you intend to concentrate, that is, to dephlegmate and make stronger: pour it into a good glass retort, of such a size that your quantity of Acid may but half fill it: set this retort in the sand-bath of a reverberating furnace: fit to it a receiver; lute it on, and give a gradual fire. There will come over into the receiver a clear liquor, the first drops of which will be but faintly Acid: this is the most aqueous part.

When the drops begin to follow one another much more slowly, raise your fire, till the liquor begin to bubble a little in the middle. Keep it thus gently boiling, till one-half or two-thirds thereof be come over into the receiver. Then let your vessels cool; unlute them; what remains in the retort pour into a crystal bottle, and stop it exactly with a glass stopple rubbed with emery.

O B S E R-

## OBSERVATIONS.

THE Acid obtained from Sulphur is generally very aqueous ; either because in preparing it water must necessarily be administered, that it may unite therewith as it separates from the Sulphur ; or because it is so greedy of moisture as to attract a great deal from the air, which must needs be admitted to make the Sulphur burn.

The Acid obtained from Vitriol, excepting that which rises last, is also mixed with a pretty considerable quantity of phlegm ; because the Vitriol, though calcined, still retains a great deal thereof, which rises with the Acid in distillation. Now, as there are many chymical experiments that will not succeed without Acids exceedingly dephlegmated, it is proper to have in a laboratory all the Acids thus conditioned : because if they happen to be too strong for particular operations, as is sometimes the case, it is very easy to lower them to the desired degree, by adding a sufficient quantity of water.

The Vitriolic Acid is much heavier and much less volatile than water. If therefore a mixture of these two liquors be exposed to the fire, the aqueous part will rise with a degree of heat which is not able to carry up the Acid : by this means they may be separated from each other : and thus is the Vitriolic Acid concentrated.

Nevertheless, as this Acid combines most closely with water, and is in a manner strongly connected with it, the water carries up some portion thereof along with it ; and hence it comes that the liquor which rises into the receiver is Acid : it is called *Spirit of Vitriol*.

As the fire carries off the most aqueous part, the other which remains in the retort increases in specific gravity. The Acid particles are brought nearer together, retain the aqueous particles more obli-



obstinately; and therefore to separate them the degree of heat must be increased.

It is usual to draw off one-half or two-thirds of the liquor that was put into the retort: but this depends on the degree of strength the Acid was of before concentration, and the degree of concentration intended to be given it.

If the Acid to be concentrated be Oil of Vitriol, from being brown or black it grows clearer as the operation advances, and at last becomes perfectly colourless and transparent; because the fat matter, which tinged it black, is dissipated during the process. Some of it deposits a white crystalline earth.

A sulphureous smell is generally perceived about the vessels in this operation. This arises from a small portion of the Phlogiston from which the Acid is not free; and 'tis this inflammable matter which gives the Oil of Vitriol its black colour: for the clearest and best rectified Oil of Vitriol will become brown, and even black, in a short time, if any inflammable matter, though in a very small quantity, be dissolved therein.

The vessels are luted in this operation, to prevent any loss of the Spirit of Vitriol, which being very acid is of use in many chymical experiments, and may itself also be again concentrated.

We observed that in this operation it is necessary the retort should be of very good glass. Indeed the Acid is so active and so strong, that if the glass be tender and have a little too much salt in its composition, it will be so corroded thereby that it will fall to pieces.

Though we directed the retort to be set in a sand-bath for this operation, it does not follow that it may not also be placed in a naked fire: on the contrary, when the heat is not conveyed through a bath the operation advances faster, and is much less tedious. But then great caution must be used, and  
6 the

the closest attention given to the management of the fire, which must be raised by almost imperceptible degrees, especially at the beginning of the operation; otherwise it is next to a certainty that the vessels will break. In general, a naked fire may be employed in almost all distillations which require a greater degree of heat than that of boiling water, or the *balneum mariæ*: the operation will be sooner finished; but it requires an experienced hand, that has by practice acquired a habit of governing the fire with judgment.

There is moreover another advantage in not using the sand-bath; which is, that if in the time of the operation you perceive the fire too fierce, you can quickly check it, either by stopping close all the apertures of the furnace, or by drawing out all or part of the lighted coals. This inconvenience is not near so easily remedied when you use the sand-bath; because when once heated it retains its heat very long after the fire is quite extinguished.

## PROCESS VII.

*To decompose Vitriolated Tartar by means of the Phlogiston; or to compose Sulphur by combining the Vitriolic Acid with the Phlogiston.*

**T**AKE equal parts of Vitriolated Tartar, and very dry Salt of Tartar, separately reduced to powder; add an eighth part of their weight of charcoal-dust; and mix the whole together very accurately. Throw this mixture into a red-hot crucible, placed in a furnace filled with burning coals. Cover it very close, and keep it very hot, till the mixture melt, which may be known by uncovering the crucible from time to time. There will

will then appear a bluish flame, accompanied with a pungent smell of Sulphur.

Take the crucible out of the fire : dissolve its contents in hot water : filter the solution through brown paper supported by a glass funnel : drop into the filtered liquor by little and little any Acid whatever. As you add the Acid the liquor will grow more and more turbid, and let fall a grey precipitate. Continue dropping in more Acid till the liquor will yield no more precipitate. Filter it a second time, to separate it from the precipitate : what remains on the filter is a true inflammable Sulphur, which you may either melt or sublime into flowers.

### OBSERVATIONS.

ALL bodies that contain the Vitriolic Acid may contribute, as well as Vitriolated Tartar, to the generation of Sulphur : so that all the neutral Salts in which this Acid is a principle, the Alums, Selénites, Gypsums, Vitriols, may be substituted for it in this experiment. All these matters, with the addition of charcoal-dust only, being fused in a crucible, constantly produce Sulphur ; because the Vitriolic Acid having a greater affinity with the Phlogiston than with any thing else, will quit its basis, whatever it be, to join with the Phlogiston of the charcoal, and therewith form a Sulphur.

The fixed Alkali added thereto helps to promote the fusion of the ingredients, which is necessary for effecting the desired combination. It also serves to unite with the Sulphur, when formed ; and thus makes the combination called *Liver of Sulphur*, which prevents the Sulphur from being consumed as soon as formed : for the fixed Alkalis, which are incombustible, hinder Sulphur from burning so easily as it would do if they were not joined with it. They may afterwards be separated from each other, by the means of any Acid whatever.

This



This process, in which Sulphur is regenerated, by re-combining together the principles of which it was originally composed, is one of the most beautiful experiments that modern Chymistry hath produced. We are indebted for it to M. Stahl; and Dr. Geoffroy hath given a particular account of it in the Memoirs of the Academy of Sciences.

Before these gentlemen Glauber and Boyle had indeed published methods of producing Sulphur. Glauber made use of his *Sal mirabile* and powdered charcoal: Boyle employed the Vitriolic Acid and Oil of Turpentine. But neither of those Chymists understood the true theory of their operations: they did not thoroughly know the principles of Sulphur: they did not imagine they had composed Sulphur; they thought they only extracted what they supposed to exist previously in the matters they employed in their experiments.

M. Stahl was the first who discovered and explained the nature of Sulphur, and proved that in Glauber's and Boyle's experiments Sulphur was actually produced, by uniting together the principles of which it is constituted. This beautiful experiment gives the strongest lustre of evidence to the theory of the composition of that mixt, which acts such a capital part in Chymistry; and it can no longer be doubted that Sulphur is actually a combination of the Vitriolic Acid with the Phlogiston.

Besides this important truth, our process for composing Sulphur by art proves several others that are equally essential and fundamental.

The first is that the Vitriolic Acid hath a greater affinity with the Phlogiston than with any other thing, seeing it quits metallic and earthy substances, as well as Alkaline salts, in order to combine therewith.

The second is that Sulphur combines with fixed Alkalis without suffering any decomposition; seeing  
it

it may be separated from them entire and unaltered; and seeing that very Sulphur, which is naturally indissoluble in water, is rendered soluble therein by the union it hath contracted with the fixed Alkali.

The third is that the Vitriolic Acid, which when it is pure hath the greatest affinity with Alkalis of any Acid whatever, loses a great deal of that affinity by contracting an union with the Phlogiston; seeing the weakest Acids are capable of decomposing the Liver of Sulphur, and separating the Sulphur from the Alkali. And this also confirms one of the general propositions concerning affinities advanced in our theory; to wit, that the affinities of compound or mixed substances are weaker than those of the same substances in a purer and more simple state.

## CHAP. II.

### *Of the NITROUS ACID.*

#### PROCESS I.

*To extract Nitre out of nitrous Earths and Stones.  
The Purification of Salt Petre. Mother of Nitre.  
Magnesia.*

**T**AKE any quantity of nitrous earths or stones; reduce them to powder; and therewith mix a third part of the ashes of green-wood and quicklime. Put this mixture into a barrel or vat, and pour on it hot water to about twice the weight of the whole mass. Let it stand thus for twenty-four hours, stirring it from time to time with a stick. Then filter the liquor through brown paper, or pass it through a flannel bag, till it come clear: it will then have a yellowish colour. Boil this liquor, and evaporate till you perceive that a drop of it let fall  
on

on any cold body coagulates. Then stop the evaporation, and set your liquor in a cool place. In the space of four-and-twenty hours crystals will be formed in it, the figure of which is that of an hexagonal prism, having its opposite planes generally equal, and terminated at each extremity by a pyramid of the same number of sides. These crystals will be of a brownish colour, and deflagrate on a live coal.

Decant the liquor from these crystals; mix it with twice its weight of hot water; evaporate and crystallize as before. Repeat the same operation till the liquor will yield no more crystals: it will then be very thick, and goes by the name of *Mother of Nitre*.

### OBSERVATIONS.

EARTHS and stones that have been impregnated with animal or vegetable juices susceptible of putrefaction, and have been long exposed to the air, but sheltered from the sun and rain, are those which yield the greatest quantity of Nitre. But all sorts of earths and stones are not equally fit to produce it. None is ever found in flints or sands of a crystalline nature.

Some earths and stones abound so with Nitre, that it effloresces spontaneously on their surface, in the form of a crystalline down. This Nitre may be collected with brooms, and accordingly has the name of *Salt Peter Sweepings*. Some of this sort is brought from India.

Hitherto we are much in the dark as to the origin and generation of Nitre. Some Chymists pretend that the Nitrous Acid is diffused through the air, and gradually deposited in such earths and stones as are qualified to receive it.

Others, considering that none of it is ever obtained but from earths that have been impregnated with vegetable or animal juices, have from thence concluded



concluded those two kingdoms to be the general repositories of the Nitrous Acid; that if we do not perceive it to exist in such matters at all, or at least in any great quantity, till they have undergone putrefaction, and are in some measure incorporated with suitable earths and stones, 'tis because the Acid is so entangled with heterogeneous particles that it requires the assistance of putrefaction, and much more of filtration through an earth, to disengage it, and enable it to appear in its proper nature.

Lastly, others are of opinion that this Acid is no other than the universal or Vitriolic Acid; disguised indeed by a portion of the Phlogiston, which is combined with it in a peculiar manner by the means of putrefaction. They ground this opinion chiefly on the analogy or resemblance which they find between the Nitrous Acid and the Volatile Sulphureous Spirit. Its volatility, its pungent smell, its properties of taking fire, and of destroying the blue and violet colours of vegetables, serve them as so many proofs.

Their opinion is the more probable on this account, that even though the Nitrous Acid should actually be produced by vegetable and animal substances, yet as these substances themselves draw all their component principles from the earth, and as the Vitriolic Acid is diffused through all the soils which afford them nourishment, there is great reason to think that the Nitrous Acid is no other than the Vitriolic Acid altered by the changes and combinations it hath undergone in its passage into and through those substances. In 1750 the Royal Academy of Sciences at Berlin proposed an account of the generation of Nitre as the subject for their prize, which was conferred on a Memoir wherein his last opinion was supported by some new and very judicious experiments.

The process by which our Salt-petre makers extract Nitre in quantities, out of rubbish and nitrous earths, is very nearly the same with that here set down: so that I shall not enter into a particular account of it. I shall only take notice of one thing, which it is of some consequence to know; namely, that there is no nitrous earth which does not contain sea-salt also. The greatest quantities of this salt are to be found in those earths which have been drenched with urine, or other animal excrements. Now as the rubbish of old houses in great cities is in this class, it comes to pass that when the Salt-petre workers evaporate a nitrous lixivium drawn from that rubbish, as soon as the evaporation is brought to a certain pitch, a great many little crystals of sea-salt form in the liquor, and fall to the bottom of the vessel.

The Salt-petre workers in France call these saline particles *the Grain*, and take great care to separate them from the liquor, (which as long as it continues hot keeps the salt-petre dissolved) before they set it to crystallize. This fact seems a little singular, considering that sea-salt dissolves in water more easily than salt-petre, and crystallizes with more difficulty. In order to discover the cause of this phenomenon, we must recollect some truths delivered in our theoretical Elements. The first is, that water can keep but a determinate quantity of any salt in solution, and that if water fully saturated with a salt be evaporated, a quantity of salt will crystallize in proportion to the quantity of water evaporated. The second is, that those salts which are the most soluble in water, particularly those which run in the air, will dissolve in cold and in boiling water equally; whereas much greater quantities of the other salts will dissolve in hot and boiling water than in cold water. These things being admitted, when we know that sea-salt is one of the first sort and salt-petre of the second

the reason why sea-salt precipitates in the preparation of salt-petre appears at once. For -

When the solution of salt-petre and sea-salt comes to be evaporated to such a degree that it contains as much sea-salt as it possibly can, this salt must begin to crystallize, and continue to do so gradually as the evaporation advances. But because at the same time it does not contain as much salt-petre as it can hold, seeing it is capable of dissolving a much greater quantity thereof when it is boiling hot than when it is cold, this last named salt will not crystallize so soon. If the evaporation were continued till the case of the salt-petre came to be the same with that of the sea-salt, then the salt-petre also would begin to crystallize gradually in proportion to the water evaporated, and the two salts would continue crystallizing promiscuously together: but it is never carried so far; nor is it ever necessary; for as the water cools it becomes more and more incapable of holding in solution the same quantity of salt-petre as when it was boiling hot.

And then comes the very reverse, with regard to the crystallizing of the two salts; for then the Salt-petre shoots, and not the Sea-salt. The reason of this fact also is founded on what has just been said. The Sea-salt, of which cold water will dissolve as much as boiling water, and which owed its crystallizing before only to the evaporation, now ceases to crystallize as soon as the evaporation ceases; while the Salt-petre, which the water kept dissolved only because it was boiling hot, is forced to crystallize merely by the cooling of the water.

When the solution of Salt-petre has yielded as many crystals of that Salt as it can yield by cooling, it is again evaporated, and being then suffered to cool yields more crystals. And thus they continue evaporating and crystallizing, till the liquor will afford no more crystals. It is plain that as the Salt-



petre crystallizes, the proportion of Sea-salt to the dissolving liquor increases; and as a certain quantity of water evaporates also during the time employed in crystallizing the Salt-petre, a quantity of Sea-salt, proportioned to the water so evaporating, must crystallize in that time: and this is the reason why Salt-petre is adulterated with a mixture of Sea-salt. It likewise follows that the last crystals of Nitre, obtained from a solution of Salt-petre and Sea-salt, contain much more Sea-salt than the first.

From all that has been said concerning the crystallization of Salt-petre and Sea-salt, it is easy to deduce the proper way of purifying the former of these two Salts from a mixture of the latter. For this purpose the Salt-petre to be refined need only be dissolved in fair water. The proportion between the two salts in this second solution is very different from what it was in the former; for it contains no more Sea-salt than what had crystallized along with the Salt-petre under favour of the evaporation, the rest having been left dissolved in the liquor that refused to yield any more nitrous crystals.

As there is therefore a much greater quantity of Salt-petre than of Sea-salt in this second solution, it is easy to evaporate it to such a degree that a great deal of Salt-petre shall crystallize, while much more of the water must necessarily be evaporated before any of the Sea-salt will crystallize.

However, the Salt-petre is not yet entirely free from all mixture of Sea-salt by this first purification for the crystals obtained from this liquor, in which Sea-salt is dissolved, are still encrusted, and, as were, infected therewith: hence it comes, that, to refine the Salt-petre thoroughly, these crystallizations must be repeated four or five times.

The Salt-petre men commonly content themselves with crystallizing it thrice, and call the produce Salt-petre.

petre of the first, second, or third shoot, according to the number of crystallizations it has undergone. But their best refined Salt-petre, even that of the third shooting, is not yet sufficiently pure for Chymical experiments that require much accuracy: so that it must be further purified; but still by the same method.

The Nitrous Acid is not pure in the earths and stones from which it is extracted. It is combined partly with the very earth in which it is formed, and partly with the Volatile Alkali produced by the putrefaction of the vegetable or animal matters that concurred to its-generation. A Fixed Alkali and Quick-lime are added to the lixivium of a nitrous earth, in order to decompose the nitrous Salt formed in that earth, and to separate the Acid from the Volatile Alkali and the absorbent earth with which it is united: thence comes that copious sediment which appears in the lye at the beginning of the evaporation. These matters form with that Acid a true Nitre, much more capable than the original Nitrous Salts of crystallization, detonation, and the other properties which are essential thereto. The basis of Nitre is therefore a Fixed Alkali mixed with a little lime.

The Mother of Nitre, which will yield no more crystals, is brown and thick: by evaporation over fire it is further inspissated, and becomes a dry, solid body; which however being left to itself soon gives, and runs into a liquor. This water still contains a good deal of Nitre, Sea-salt, and the Acids of these Salts united with an absorbent earth. It contains moreover a great deal of a fat, viscid matter, which prevents it crystallizing.

All saline solutions in general, after having yielded a certain quantity of crystals, grow thick, and refuse to part with any more, though they still contain much Salt. They are all called *Mother-waters*, as

well as that which hath yielded Nitre. The Mother-waters of different Salts may prove the subjects of curious and useful enquiries.

If a Fixed Alkali be mixed with the Mother of Nitre, a copious white precipitate immediately falls, which being collected and dried is called *Magnesia*. This precipitate is nothing but the absorbent earth that was united with the Nitrous Acid, together with a good deal of the lime that was added, and was also united with that Acid, from which they are now separated from the Fixed Alkali, according to the usual laws of affinities.

The Vitriolic Acid poured upon Mother of Nitre causes many Acid vapours to rise which are a compound of the nitrous and marine Acids, that is, an *Aqua regia*. On this occasion also there falls a large quantity of a white powder, which is still called *Magnesia*; yet it differs from the former in that it is not, like it, a pure absorbent earth, but combined with the Vitriolic Acid.

An *Aqua regis* may also be drawn from nitrous earths by the force of fire only, without the help of any additament.

## PROCESS II.

*To decompose Nitre by means of the Phlogiston. Nitre fixed by Charcoal. Clyffus of Nitre. Sal Polychrestum.*

**T**AKE the purest Salt-petre in powder; put it into a large crucible, which it may but half fill; set the crucible in a common furnace, and surround it with coals. When it is red-hot the Nitre will melt, and become as fluid as water. Then throw into the crucible a small quantity of charcoal dust: the Nitre and the charcoal will immediately deflagrate with violence; and a great commotion will be



be raised, accompanied with a considerable hissing, and abundance of black smoke. As the charcoal wastes, the detonation will abate, and cease entirely as soon as the coal is quite consumed.

Then throw into the crucible the same quantity of charcoal-dust as before, and the same phenomena will be repeated. Let this coal also be consumed; then add more, and go on in the same manner till you can excite no further deflagration; always observing to let the burning coal be entirely consumed before you add any fresh. When no deflagration ensues, the matter contained in the crucible will have lost much of its fluidity.

### OBSERVATIONS.

NITRE will not take fire, unless the inflammable matter added to it be actually burning, or the Nitre itself red-hot, and so thoroughly ignited as immediately to kindle it. Therefore, if you would procure the detonation of Nitre with charcoal, and make use of cold charcoal, as in the process, the Nitre in the crucible must be red-hot, and in perfect fusion: but you may also use live coals, and then the Nitre need not be red-hot.

It is proper that the crucible used in this experiment should be only half full; for during the detonation its contents swell, and might run over without this precaution. For the same reason the charcoal-dust is to be thrown in by little and little; and that first put in must be entirely consumed before any fresh be added.

The matter remaining in the crucible after the operation is a very strong Fixed Alkali. Being exposed to the air it quickly attracts the moisture thereof, and runs into a liquor. It is called *Alkalized Nitre*, or to distinguish it from Nitre alkalized by other inflammable matters, *Nitre fixed by charcoal*.

However, this Alkali is not absolutely pure. It still contains a portion of the Nitre that hath not been decomposed: for when there remains but a little of this Salt mixed with a great quantity of Alkali, which is not inflammable, the Alkali in some measure shelters it, coats it over, and obstructs that immediate contact with the inflammable matters applied, which is necessary to make it deflagrate.

If the Fixed Alkali be desired perfectly free from any mixture of undecomposed Nitre, the fire about the crucible must be considerably increased as soon as the detonation is entirely over; the matter must be made to flow, which requires a much stronger heat than would melt Nitre, and kept thus in fusion for about an hour. After this no perfect Nitre will be found therein: for the little that was left, being unable to abide the force of the fire, as not being extremely fixed, either is entirely dissipated, or loses its Acid, which is carried off by the violence of the heat.

Fixed Nitre contains also a portion of the earth that constituted the basis of the Nitre, which is no other than the lime employed in its crystallization, or else some of the earth with which its Acid was originally combined, and which it retained in crystallizing. When Nitre is deflagrated with such matters as produce ashes, these ashes likewise furnish a certain quantity of earth, which mixes with the Fixed Alkali. To separate these several earths from the Alkali, nothing more is requisite than to let it run *per deliquium*, or to dissolve it in water, and filter the solution through brown paper. Whatever is saline will pass through the filtre with the water, and the earthy part will be left upon it.

The Nitrous Acid is not only dissipated during the deflagration of the Nitre, but is even destroyed, and perfectly decomposed. The smoke that rises during the operation has not the least odour of an

an Acid. Its nature may be accurately examined by catching it in proper vessels, and condensing it into liquor.

Nitre differs from Sulphur, and from all other inflammable bodies whatever, in this, that the free access of the air is indispensably necessary to make any of the others burn; whereas Nitre, and Nitre only, is capable of burning in close vessels: and this property furnishes us with the means of collecting the vapours which it discharges in deflagration.

For this purpose to a tubulated earthen retort you must fit two or three large adopters: set the retort in a furnace; and under it make a fire sufficient to keep its bottom moderately red. Then take a small quantity, two or three pinches for example, of a mixture of three parts of nitre with one of charcoal-dust, and drop it into the retort through its tube, which must be uppermost, and immediately stopped close. A detonation instantly ensues, and the vapours that rise from the inflamed mixture of Nitre and charcoal, passing out through the neck of the retort into the adopters, circulate therein for a while, and at last condense into a liquor.

When the detonation is over, and the vapours condensed, or nearly so, drop into the retort another equal quantity of the mixture; and repeat this till you find there is liquor enough in the recipients to be examined with ease and accuracy. This liquor is almost insipid, and shews no tokens of acidity; or at most but very slight ones. It is called *Clyffus* of Nitre.

It is easy to perceive why several adopters are required in this experiment, and why a very small quantity of the mixture must be introduced into the retort at once. The explosion, and the quantity of air and vapours discharged on this occasion, would quickly burst the vessels, if all these precautions were not attended to. This plainly appears from  
the



the terrible effects of gunpowder, which is nothing but a composition of Nitre, Sulphur, and Charcoal.

Nitre is also decomposed and takes fire by the means of Sulphur; but the circumstances and the result differ widely from those produced therewith by charcoal, or any other inflammable body.

Nitre deflagrates with Sulphur on account of the Phlogiston which the latter contains. If one part of Sulphur be mixed with two or three parts of Nitre, and the mixture thrown by little and little into a red-hot crucible, upon every projection there arises a detonation accompanied with a vivid flame.

The vapours discharged on this occasion have the mingled smell of a Sulphureous Spirit and Spirit of Nitre; and if they be collected by means of a tubulated retort, and such an apparatus of vessels as was used in the preceding experiment, the liquor contained in the recipients is found to be an actual mixture of the Acid of Sulphur, the Sulphureous Spirit, and the Acid of Nitre; the first being in greater quantity than the other two, and the second greater than the last.

Nor is the remainder after detonation a Fixed Alkali, as in the former experiments; but a Neutral Salt, consisting of the Acid of Sulphur combined with the Alkali of Nitre; a sort of Vitriolated Tartar known in medicine by the name of *Sal Polychrestum*.

There are evidently two essential differences between this last experiment and the preceding one. What remains after the deflagration of Nitre with Sulphur is not a Fixed Alkali: and moreover, the vapours emitted in the operation are impregnated with a quantity of the Nitrous Acid; which is not the case when Nitre is decomposed by any other inflammable matter which contains no Vitriolic Acid.

The reason of these differences is naturally deducible from what hath been already said concerning the properties

properties of the Vitriolic and Nitrous Acids. We have seen that by burning Sulphur its Acid is not decomposed, but only separated from its Phlogiston. We also know that its Acid has a great affinity with Fixed Alkalis. These things being granted, it follows that, as soon as the Nitrous Acid quits its Alkaline basis, by deflagrating with the Phlogiston of the Sulphur, the Acid of this very Sulphur, being set at liberty by that deflagration, must unite with the Alkaline basis deserted by the Acid of Nitre, and therewith form a Neutral Salt. Hence, instead of a Fixed Alkali, we find at the end of the operation a sort of Vitriolated Tartar; the Acids of Sulphur and of Vitriol being the same, as is evident from what hath been above said concerning them.

In order to discover the cause of the other phenomenon, we must recollect two things advanced in our Elements of the Theory; to wit, that the affinity of the Vitriolic Acid with Fixed Alkalis is greater than that of the Nitrous Acid; and again, that the Nitrous Acid is not capable of combining and taking fire with the Phlogiston, but when it is in the form of a Neutral Salt, that is, when it is united with some alkaline, earthy, or metallic basis. If those two principles be applied to the effect in question, the solution is easy and natural. For, in the deflagration of Nitre with Sulphur, the Phlogiston is not the only substance capable of separating the Nitrous Acid from its basis: the Acid of the Sulphur, more and more of which is set at liberty as the Phlogiston is consumed, is also capable of producing the same effect; but with this difference, that the portion of the Nitrous Acid which is detached from its Alkali by the Phlogiston is at the same instant set on fire and decomposed by that union; whereas the portion thereof which is separated by the Vitriolic Acid, being when so separated incapable of uniting with the Phlogiston, and of consuming there-

threwith, is preserved entire, and rises in vapours, together with that portion of the Vitriolic Acid which could not unite with the basis of the Nitre.

### PROCESS III.

*To decompose Nitre by means of the Vitriolic Acid.*

*The Smoking Spirit of Nitre. Sal de duobus.*

*The Purification of Spirit of Nitre.*

**T**AKE equal parts of well purified Nitre and Green Vitriol : dry the Nitre thoroughly, and bruise it to a fine powder. Calcine the Vitriol to redness : reduce it likewise to a very fine powder ; and mingle these two substances well together. Put the mixture into an earthen long-neck, or a good glass retort coated, of such a size that it may be but half full.

Set this vessel in a reverberating furnace covered with its dome ; apply a large glass receiver, having a small hole in its body, stopped with a little lute. Let this receiver be accurately luted to the retort with the fat lute, and the joint covered with a slip of canvas smeared with lute made of quicklime and the white of an egg. Heat the vessels very gradually. The receiver will soon be filled with very dense red vapours, and drops will begin to distil from the nose of the retort.

Continue the distillation, increasing the fire a little when you observe the drops to follow each other but slowly, so that above two thirds of a minute passes between them ; and, in order to let out the redundant vapours, open the small hole in the receiver from time to time. Towards the end of the operation raise the fire so as to make the retort red. When you find that, even when the retort is red-hot, nothing more comes over, unlute the receiver, and without delay pour the liquor it contains



tains into a crystal bottle, and close it with a crystal stopple ground in its neck with emery. This liquor will be of a reddish yellow colour, smoking exceedingly, and the bottle containing it will be constantly filled with red fumes like those observed in the receiver.

## OBSERVATIONS.

THE Vitriolic Acid having a greater affinity with Fixed Alkalis than with any other substance, the Phlogiston excepted, and being in the Vitriol united with a ferruginous basis, will naturally quit that basis to join with the Fixed Alkali of the Nitre; the Acid whereof being weaker than the Vitriolic, as we have already observed on several occasions, must needs be thereby expelled from its basis. The Nitre therefore is decomposed by the Vitriol, and its Acid being set at liberty, is carried up by the force of the fire.

Indeed the Nitrous Acid, being thus separated from its alkaline basis, might be expected to combine with the ferruginous basis of the Vitriol: but as it has, like all other Acids, much less affinity with Metallic substances than with Alkalis, even a moderate degree of fire is sufficient to separate it from them. Moreover, this Acid hath either no effect, or very little, upon iron that has lost much of its Phlogiston by contracting an union with any Acid; which is the case of the ferruginous basis of Vitriol.

By the process here delivered a very strong, perfectly dephlegmated, and vastly smoking Spirit of Nitre is obtained. If the precautions of drying the Nitre and calcining the Vitriol be neglected, the Acid that comes over, greedily attracting the water contained in these salts, will be very aqueous, will not smoke, and will be almost colourless, with a very slight tinge of lemon.

The fumes of highly concentrated Spirit of Nitre, such as that obtained by the above process, are light, corrosive, and very dangerous to the lungs; being no other than the most dephlegmated part of the Nitrous Acid. The person therefore who unlutes the vessels, or pours the liquor out of the receiver into the bottle, ought with the greatest caution to avoid drawing them in with his breath; and for that reason ought to place himself so that a current of air, either natural or artificial, may carry them off another way. It is also necessary that care be taken, during the operation, to give the vapours a little vent every now and then, by opening the small hole in the recipient; for they are so elastic, that, if too closely confined, they will burst the vessels.

When the operation is over, you will find a red mass at the bottom of the retort, cast as it were in a mould. This is a Neutral Salt of the nature of Vitriolated Tartar, resulting from the union of the Acid of the Vitriol with the Alkaline basis of the Nitre.

The ferruginous basis of the Vitriol, which is mixed with this salt, gives it the red colour. To separate it therefrom, you must pulverise it, dissolve it in boiling water, and filter the solution several times through brown paper; because the ferruginous earth of the vitriol is so fine, that some of it will pass through the first time. When the solution is very clear, and deposits no sediment, let it be set to shoot, and it will yield crystals of Vitriolated Tartar; to which Chymists have given the peculiar title of *Sal de duobus*.

In this *Caput mortuum* we frequently find, besides the ferruginous earth of Vitriol, a portion of Nitre and Vitriol not decomposed; either because the two Salts were not thoroughly mingled, or because the  
fire

fire was not raised high enough towards the end of the operation.

Nitre may also be decomposed, and its Acid obtained, by the interposition of any of the other Vitriols, Alums, Gypsums, Boles, Clays; in short, by means of any compound in which the Vitriolic Acid is found, provided it have not a Fixed Alkali for its basis.

The distillers of *Aqua fortis*, who make large quantities at a time, and who use the least chargeable methods, do their business by the means of earths impregnated with the Vitriolic Acid; such as Clays and Boles. With these earths they accurately mix the Nitre from which they intend to draw their Spirit: this mixture they put into large oblong earthen pots, having a very short curved neck, which enters a recipient of the same matter and form. These vessels they place in two rows opposite to each other in long furnaces, and cover them over with bricks cemented with Windsor-loam, which serves for a reverberatory: then they light the fire in the furnace, making it at first very small, only to warm the vessels; after which they throw in wood, and raise the fire till the pots grow quite red hot, in which degree they keep it up till the distillation is entirely finished.

The Acid of Nitre may also be separated from its basis by means of the pure Vitriolic Acid. For this purpose the Nitre from which you mean to extract the Acid must be finely pulverized, put into a glass retort, and a third part of its weight of concentrated Oil of Vitriol poured on it: the retort must be placed in a reverberating furnace, and a receiver, like that used in the preceding operation, expeditiously applied.

As soon as the Oil of Vitriol touches the Nitre the mixture grows hot, and copious red fumes begin



begin to appear: some drops of the Acid come over even before the fire is kindled in the furnace.

On this occasion the fire must be moderate; because the Vitriolic Acid, being clogged by no basis, acts upon the Nitre much more briskly, and with much greater effect; than when it is not pure.

This operation may be performed by a sand heat; which is a speedy and commodious way of obtaining the Nitrous Acid. In other respects the precautions recommended in the preceding experiment must be carefully observed here, both in distilling the Acid, and in taking it out of the receiver.

The Spirit of Nitre extracted by this method is as strong, and smokes as much, as that obtained by calcined Vitriol, provided the oil of Vitriol made use of be well concentrated; but it is generally tainted by the admixture of a small portion of the Vitriolic Acid, which, having no basis of its own to restrain it, is carried up by the heat before it can lay hold of the basis of the Nitre.

There are several experiments in Chymistry that succeed equally well whether the Nitrous Acid be or be not thus adulterated with a mixture of the Vitriolic Acid; but there are some; as we shall see, that will not succeed without a Spirit of Nitre so mixed. If the Acid be distilled with a view to such experiments, it must be kept as it is. But most experiments require the Spirit of Nitre to be absolutely pure; and if it be intended for such, it must be perfectly cleansed from the Vitriolic taint.

This is easily effected by mixing your Spirit with very pure Nitre, and distilling it a second time. The Vitriolic Acid, with which this Spirit of Nitre is adulterated, coming in contact with a great quantity of undecomposed Nitre, unites with its Alkaline basis, and expels a proportionable quantity of the Nitrous Acid.

In the retort made use of to distil the Nitrous Acid, by means of the pure Vitriolic Acid, is found a *Caput mortuum* differing from that left after the distillation of the same Acid by the interposition of Vitriol, in as much as it contains no red ferruginous earth. This is a very white saline mass, moulded in the bottom of the retort: if you pound it, dissolve it in boiling water, and evaporate the solution, it will shoot into crystals of Vitriolated Tartar: sometimes also it contains a portion of undecomposed Nitre, which shoots after the Vitriolated Tartar, because it is much more soluble in water.

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### C H A P. III.

#### *Of the MARINE ACID.*

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#### P R O C E S S I.

*To extract Sea-Salt from Sea-Water, and from Brine-Springs. Epsom Salt.*

**F**ILTER the salt water from which you intend to extract the Salt: evaporate it by boiling till you see on its surface a dark pellicle: this consists wholly of little crystals of salt just beginning to shoot: now slacken the fire, that the brine may evaporate more slowly, and without any agitation. The crystals, which at first were very small, will become larger, and form hollow truncated pyramids, the apices whereof will point downwards, and their bases be even with the surface of the liquor.

These pyramidal crystals are only collections of small cubical crystals concentered into this form.

When they have acquired a certain magnitude they fall to the bottom of the liquor. When they come to be in such heaps as almost to reach the surface of the liquor, decant it from them, and continue the evaporation till no more crystals of Sea-salt will shoot.

### OBSERVATIONS.

THE Acid of Sea-salt is scarce ever found, either in Sea-water or in the earth, otherwise than united with a fixed Alkali of a particular kind, which is its natural basis; and consequently it is in the form of a Neutral Salt. This Salt is plentifully dissolved in the waters of the ocean, and when obtained therefrom bears the name of *Sea-Salt*. It is also found in the earth in vast crystalline masses, and is then called *Sal-Gem*: so that Sea-salt and Sal-Gem are but one and the same sort of Salt, differing very little from each other, except as to the places where they are found.

In the earth are also found springs and fountains, whose waters are strong brines, a great deal of Sea-Salt being dissolved in them. These springs either rise directly from the Sea, or run through some mines of Sal-gem, of which they take up a quantity in their passage.

As the same, or at least nearly the same, quantity of Sea-salt will continue dissolved in cold water as boiling water will take up, it cannot shoot, as Nitric acid does, by the mere cooling of the water in which it is dissolved: it crystallizes only by the means of evaporation, which continually lessens the proportion of the water to the Salt; so that it is always capable of containing just so much the less Sea-salt the more there is crystallized.

The brine should not boil after you perceive the pellicle of little crystals beginning to form on its surface; for the calmness of the liquor allows them  
for



form more regularly, and become larger. Nor after this should the evaporation be hurried on too fast; for a saline crust would form on the liquor, which, by preventing the vapours from being carried off, would obstruct the crystallization.

If the evaporation be continued after the liquor ceases to yield any crystals of Sea-salt, other crystals will be obtained of an oblong four-sided form, which have a bitter taste, and are almost always moist. This sort of Salt is known by the name of *Epsom Salt*, which it owes to a salt spring in England, from the water of which it was first extracted. This Salt, or rather saline compound, is a congeries of Glauber's Salt and Sea-salt, in a manner confounded together, and mixed with some of the Mother of Sea-salt, in which is contained a kind of bituminous matter. These two Neutral Salts, which constitute the Epsom Salt, may be easily separated from each other, by means of crystallization only. Epsom Salt is purgative and bitter; and therefore named *Sal Catharticum Amarum*, or bitter purging Salts.

There are different methods used in great works for obtaining Sea-salt out of water in which it is dissolved. The simplest and easiest is that practised in France, and in all those countries which are not colder. On the sea-shore they lay out a sort of broad shallow pits, pans, or rather ponds, which the sea fills with the tide of flood. When the ponds are thus filled, they stop their communication with the sea, and leave the water to evaporate by the heat of the sun; by which means all the Salt contained in it necessarily crystallizes. These pits are called *Salt Ponds*. Salt can be made in this way in the summer-time only; at least in France, and other countries of the same temperature: for during the winter, when the sun has less power, and rains are frequent, this method is not practicable.

For this reason, as it often rains in the province of Normandy, the inhabitants take another way to extract Salt from sea-water. The labourers employed for this purpose raise heaps of sand on the shore, so that the tide waters and drenches them when it flows, and leaves the sand dry when it ebbs. During the interval between two tides of flood the sun and the air easily carry off the moisture that was left, and so the sand remains impregnated with all the Salt that was contained in the evaporated water. Thus they let it acquire as much salt as it can by several returns of flood, and then wash it out with fresh water, which they evaporate over a fire in leaden boilers.

To obtain the Salt from brine-springs, the water need only be evaporated: but as several of these springs contain too little Salt to pay the charges that would be incurred, if the evaporation were effected by the force of fire only, the manufacturers have fallen upon a less expensive method of getting rid of the greatest part of the water, and preparing the brine for crystallization, in much less time, and with much less fire, than would otherwise have been necessary.

The method consists in making the water fall from a certain height on a great many small spars of wood, which divide it into particles like rain. This is performed under sheds open to all the winds, which pass freely through this artificial shower. By this means the water presents to the air a great extent of surface, being indeed reduced almost entirely to surface, and the evaporation is carried on with great ease and expedition. The water is raised by pumps to the height from which it is intended to fall\*.

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\* The Marquis de Montalembert, in a Memoir read before the Academy of Sciences, proposes a new method of effecting these evaporations, together with some considerable improvements.

## PROCESS II.

*Experiments concerning the decomposition of Sea-salt, by means of the Phlogiston. Kunckel's Phosphorus.*

OF pure urine that has fermented five or six days take a quantity in proportion to the quantity of Phosphorus you intend to make: it requires about one-third part of a hogshhead to make a dram of Phosphorus. Evaporate it in iron pans, till it become clogged, hard, black, and nearly like chimney-foot; at which time it will be reduced to about a sixtieth part of its original weight before evaporation.

“ When the urine is brought to this condition, put it in several portions into so many iron pots, under which you must keep a pretty brisk fire so as to make their bottoms red, and stir it incessantly till the volatile salt and the fetid oil be almost wholly dissipated, till the matter cease to emit any smoke, and till it smell like peach-blossoms. Then put out the fire, and pour on the matter, which will now be reduced to a powder, somewhat more than twice its weight of warm water. Stir it about in this water, and leave it to soak therein for twenty-four hours. Pour off the water by inclination; dry the drenched matter, and pulverize it. The previous calcination carries off from the matter about a third of its weight, and the lixiviation washes out half the remainder.

“ With what remains thus calcined, washed, and dried, mix half its weight of gravel, or yel-

nents in the structure and disposition of the buildings necessary for that purpose. They are called by the French *Batiments de graduation*; which may properly enough be rendered *Brine-oufcs*.



“ low freestone rasped, having sifted out and  
 “ thrown away all the finest particles. River-sand  
 “ is not proper on this occasion, because it flies in  
 “ a hot fire. Then add to this mixture a sixteenth  
 “ part of its weight of charcoal, made of beech, or  
 “ of any other wood except oak, because that also  
 “ flies. Moisten the whole with as much water as  
 “ will bring it to a stiff paste, by working and  
 “ kneading it with your hands: now introduce it  
 “ into your retort, taking care not to daub its  
 “ neck. The retort must be of the best earth,  
 “ and of such a size, that when your matter is in  
 “ it, a full third thereof shall still be empty.

“ Place your retort, thus charged, in a reverbe-  
 “ rating furnace, so proportioned, that there may  
 “ be an interval of two inches all round between  
 “ the sides of the furnace and the bowl of the re-  
 “ tort, even where it contracts to form the neck,  
 “ which should stand inclined at an angle of sixty  
 “ degrees. Stop all the apertures of the furnace,  
 “ except the doors of the fire-place and ash-hole.

“ Fit on to the retort a large glass ballon two-  
 “ thirds full of water, and lute them together, as  
 “ in distilling the Smoaking Spirit of Nitre. In  
 “ the hinder part of this ballon, a little above the  
 “ surface of the water, a small hole must be bored.  
 “ This hole is to be stopped with a small peg of  
 “ birch-wood, which must slip in and out very ea-  
 “ sily, and have a small knob to prevent its falling  
 “ into the ballon. This peg is to be pulled out  
 “ from time to time, that by applying the hand  
 “ to the hole it may be known whether the air  
 “ rarefied by the heat of the retort, issues out with  
 “ too much or too little force.

“ If the air rushes out with too much rapidity  
 “ and with a hissing noise, the door of the ash-hole  
 “ must be entirely shut, in order to slacken the fire.  
 “ If it do not strike pretty smartly against the hand

“ th

“ that door must be opened wider, and large coals  
 “ thrown into the fire-place to quicken the fire  
 “ immediately.

“ The operation usually lasts four-and-twenty  
 “ hours; and the following signs shew that it will  
 “ succeed, provided the retort resist the fire.

“ You must begin the operation with putting  
 “ some unlighted charcoal in the ash-hole, and a  
 “ little lighted charcoal at the door thereof, in or-  
 “ der to warm the retort very slowly. When the  
 “ whole is kindled, push it into the ash-hole, and  
 “ close the door thereof with a tile. This moderate  
 “ heat brings over the phlegm of the mixture.  
 “ The same degree of fire must be kept up four  
 “ hours, after which some coals may be laid on  
 “ the grate of the fire-place, which the fire under-  
 “ neath will kindle by degrees. With this second  
 “ heat brought nearer the retort, the ballon grows  
 “ warm, and is filled with white vapours, which  
 “ have the smell of fetid oil. In four hours after,  
 “ this vessel will grow cool and clear; and then  
 “ you must open the door of the ash-hole one  
 “ inch, throw fresh coals into the fire-place every  
 “ three minutes, and every time shut the door of  
 “ it, lest the cold air from without should strike  
 “ against the bottom of the retort and crack it.

“ When the fire has been kept up to this degree  
 “ for about two hours, the inside of the ballon be-  
 “ gins to be netted over with a volatile salt of a  
 “ singular nature, which cannot be driven up but  
 “ by a very violent fire, and which smells pretty  
 “ strong of peach-kernels. Care must be taken  
 “ that this concrete salt do not stop the little hole  
 “ in the ballon: for in that case it would burst, the  
 “ retort being then red-hot, and the air exceedingly  
 “ rarefied. The water in the ballon, being heated  
 “ by the vicinity of the furnace, exhales vapours

“ which dissolve this sprigged salt, and the ballon  
“ clears up in half an hour after it has ceased rising.

“ In about three hours from the first appearance  
“ of this salt, the ballon is again filled with new  
“ vapours, which smell like Sal Ammoniac thrown  
“ upon burning coals. They condense on the sides  
“ of the receiver into a salt which is not branched  
“ like the former, but appears in long perpendi-  
“ cular streaks, which the vapours of the water do  
“ not dissolve. These white vapours are the fore-  
“ runners of the Phosphorus, and a little before  
“ they cease to rise they lose their first smell of Sal  
“ Ammoniac, and acquire the odour of garlick.

“ As they ascend with great rapidity, the little  
“ hole must be frequently opened, to observe whe-  
“ ther the hissing be not too strong; for in that  
“ case it would be necessary to shut the door of the  
“ ash-hole quite close. These white vapours con-  
“ tinue two hours. When you find they cease  
“ rising, make a small passage through the dome,  
“ by opening some of its registers, that the flame  
“ may just begin to draw. Keep up the fire in  
“ this mean state till the first volatile Phosphorus  
“ begins to appear.

“ This appears in about three hours after the  
“ white vapours first begin to rise. In order to  
“ discover it, pull out the little birchen peg once  
“ every minute, and rub it against some hot part  
“ of the furnace, where it will leave a trail of  
“ light, if there be any Phosphorus upon it.

“ Soon after you observe this sign, there will  
“ issue out through the little hole of the ballon a  
“ stream of bluish light, which continues of a  
“ greater or shorter extent to the end of the opera-  
“ tion. This stream or spout of light does not burn  
“ If you hold your finger against it for twenty or  
“ thirty seconds, the light will adhere to it; and if

“ you



“ you rub that finger over your hand, the light  
 “ will besmear it, and render it luminous.

“ But from time to time this streamer darts out  
 “ to the length of seven or eight inches, snapping  
 “ and emitting sparks of fire; and then it burns  
 “ all combustible bodies that come in its way.  
 “ When you observe this, you must manage the  
 “ fire very warily, and shut the door of the ash-  
 “ hole quite close, yet without ceasing to throw  
 “ coals into the fire-place every two minutes.

“ The Volatile Phosphorus continues two hours;  
 “ after which the little spout of light contracts to  
 “ the length of a line or two: and now is the time  
 “ for pushing your fire to the utmost: immediately  
 “ set the door of the ash-hole wide open, throw  
 “ billets of wood into it, unstop all the registers  
 “ of the reverberatory, supply the fire-place with  
 “ large coals every minute: in short, for six or  
 “ seven hours all the inside of the furnace must be  
 “ kept of a white heat, so that the retort shall  
 “ not be distinguishable.

“ In this fierce extremity of heat the true Phos-  
 “ phorus distils like an oil, or like melted wax:  
 “ one part thereof floats on the water in the reci-  
 “ pient, the other falls to the bottom. At last,  
 “ the operation is known to be quite over when  
 “ the upper part of the ballon, in which the vola-  
 “ tile Phosphorus appears condensed in a blackish  
 “ film, begins to grow red: for this shews that the  
 “ Phosphorus is burnt where the red spot appears.  
 “ You must now stop all the registers, and shut  
 “ all the doors of the furnace, in order to smother  
 “ the fire; and then close up the little hole in the  
 “ ballon with fat lute or bees-wax. In this con-  
 “ dition the whole must be left for two days; be-  
 “ cause the vessels must not be separated till they  
 “ are perfectly cold, lest the Phosphorus should  
 “ take fire.

“ As soon as the fire is out, the ballon, which  
“ is then in the dark, presents a most agreeable  
“ object: all the empty part thereof above the  
“ water seems filled with a beautiful blue light:  
“ which continues for seven or eight hours, or as  
“ long as the ballon keeps warm, never disap-  
“ pearing till it is cooled.

“ When the furnace is quite cold take out the  
“ vessels, and separate them from each other as  
“ neatly as possible. With a linen cloth wipe away  
“ all the black stuff you find in the mouth of the  
“ ballon; for if that filth should mix with the Phos-  
“ phorus, it would hinder it from being transpa-  
“ rent when moulded. This must be done with  
“ great expedition: after which pour into the bal-  
“ lon two or three quarts of cold water, to acce-  
“ lerate the precipitation of the Phosphorus that  
“ swims at top. Then agitate the water in the bal-  
“ lon, to rinse out all the Phosphorus that may  
“ stick to the sides; pour out all the water thus  
“ shaken and turbid, into a very clean earthen pan,  
“ and let it stand till it grows clear. Then decant  
“ this first useless water, and on the blackish sedi-  
“ ment, left at the bottom of the pan, pour some  
“ boiling water to melt the Phosphorus; which  
“ thereupon unites with the fuliginous matter, or  
“ volatile Phosphorus, that precipitated with it,  
“ both together forming a mass of the colour of  
“ slate. When this water, in which you have melt-  
“ ed the Phosphorus, is cool enough, take out the  
“ Phosphorus, throw it into cold water, and there-  
“ in break it into little bits in order to mould it.  
“ Then take a matraass, having a long neck  
“ somewhat wider next the body than at its  
“ mouth: cut off half the body, so as to make a  
“ funnel of the neck-part, the smaller end of which  
“ must be stopped with a cork. The first mould  
“ being thus prepared, plunge it endwise, with its  
“ mouth

“ mouth uppermost, in a vessel full of boiling  
 “ water, and fill it with that water. Into this fun-  
 “ nel throw the little bits of your slate-like mass,  
 “ which will melt again in this hot water, and fall  
 “ so melted to the bottom of the tube. Stir this  
 “ melted matter with an iron wire, to promote the  
 “ separation of the Phosphorus from the fuligi-  
 “ nous matter with which it is fouled, and which,  
 “ being less ponderous than the Phosphorus, will  
 “ gradually rise above it towards the upper part  
 “ of the cylinder.

“ Keep the water in the vessel as hot as at first,  
 “ till on taking out the tube you see the Phospho-  
 “ rus clean and transparent. Let the clear tube  
 “ cool a little, and then set it in cold water, where  
 “ the Phosphorus will congeal as it cools. When  
 “ it is perfectly congealed, pull out the cork, and  
 “ with a small rod, near as big as the tube, push  
 “ the cylinder of Phosphorus towards the mouth  
 “ of the funnel, where the feculency lies. Cut  
 “ off the black part of the cylinder, and keep it  
 “ apart: for when you have got a quantity thereof,  
 “ you may melt it over again in the same manner,  
 “ and separate the clean Phosphorus which it still  
 “ contains. As to the rest of the cylinder which  
 “ is clean and transparent, if you intend to mould  
 “ it into smaller cylinders, you may cut it in  
 “ slices, and melt it again by the help of boiling  
 “ water in glass tubes of smaller dimensions.”

#### OBSERVATIONS.

THIS process for making Phosphorus is copied  
 from the Memoirs of the Academy of Sciences for  
 the Year 1737; where it is described by M. Hellot,  
 with so much accuracy, clearness, and precision,  
 that I thought I could not do better than transcribe  
 it, without departing from the author's own expres-  
 sions, for the sake of such as may not have those  
 Memoirs.



Memoirs. We shall take occasion, in these observations, to point out some essential circumstances which I have omitted in the description of the Process, that I might not break the connection between the phenomena that happen in the course of this experiment.

It is proper to observe, in the first place, that one of the most usual causes of miscarriage in this operation is a defect of the requisite qualities in the retort employed. It is absolutely necessary to have that vessel made of the best earth, and so well made that it shall be capable of resisting the utmost violence of fire, continued for a very long time; as appears by the description of the process. The retorts commonly sold by potters, and other earthen ware-men, are not fit for this operation; and M. Hellot was obliged to send to Hesse-Cassel for such as he wanted.

We shall, in the second place, observe with M. Hellot that, “ before you set your retort in  
 “ the furnace, it is proper to make an essay of your  
 “ matter, to see if there be reason to hope for suc-  
 “ cess. For this purpose put about an ounce there-  
 “ of into a small crucible, and heat it till the vessel  
 “ be red. The mixture, after having smoked,  
 “ ought to chop or crack without puffing up, or  
 “ even rising in the least. From these cracks will  
 “ issue undulating flames, white and bluish, dart-  
 “ ing upwards with rapidity. This is the first vo-  
 “ latile Phosphorus, which occasions all the dan-  
 “ ger of the operation. When these first flashes  
 “ are over, increase the heat of your matter by  
 “ laying a large live coal upon the crucible. You  
 “ will then see the second Phosphorus, like a lu-  
 “ minous, steady vapour, of a colour inclining to  
 “ violet, covering the whole surface of the matter:  
 “ it continues for a very long time, and diffuses a  
 “ smell of garlick, which is the distinguishing  
 “ odour of the Phosphorus you are seeking.

“ When

“ When this luminous vapour is entirely gone,  
 “ pour the red-hot matter out of the crucible upon  
 “ an iron plate. If you do not find one drop of salt  
 “ in fusion, but that, on the contrary, the whole  
 “ falls readily into powder, ’tis a proof that your  
 “ matter was sufficiently lixiviated, and that it  
 “ contains no more fixed Salt, or Sea-salt, if you  
 “ will, than is requisite. If you find on the plate  
 “ a drop of salt coagulated, it shews that there is  
 “ too much left in, and that there is danger of  
 “ your miscarrying in the operation ; because the  
 “ redundant salt would corrode, and eat through  
 “ the retort. In this case your matter must be  
 “ washed again, and then sufficiently dried.”

Our third observation shall be concerning the  
 furnace proper to be employed in this operation.  
 This furnace must be so constructed, that within  
 a narrow compass it may give a heat at least equal  
 to that of a glass-house furnace, or rather greater,  
 especially during the last seven or eight hours of  
 the operation. M. Hellot in his Memoir gives  
 an exact description of such a furnace.

“ As certain accidents may happen in the course  
 “ of the operation, some precautions are to be  
 “ taken against them. For instance, if the ballon  
 “ should break while the Phosphorus is distilling,  
 “ and any of it should fall on combustible bodies,  
 “ it would set them on fire, and probably burn  
 “ the laboratory, because it is not to be extin-  
 “ guished without the greatest difficulty. The  
 “ furnace must therefore be erected under some  
 “ vault, or upon a bed of brick-work raised un-  
 “ der some chimney that draws well : nor must  
 “ any furniture or utensil of wood be left near it.  
 “ If a little flaming Phosphorus should fall on a  
 “ man’s legs or hands, in less than three minutes  
 “ it would burn its way to the very bone. In such  
 “ a case nothing but urine will stop its progress.

“ If

“ If the retort crack while the Phosphorus is  
 “ distilling, there is an unsuccessful end of your  
 “ operation. It is easy to perceive this by the  
 “ stink of garlick which you will smell about the  
 “ furnace; and moreover, the flame that issues  
 “ through the apertures of the reverberatory will  
 “ be of a beautiful violet colour. The Acid of  
 “ Sea-salt always gives this colour to the flame of  
 “ such matters as are burnt along with it. But  
 “ if the retort break before the Phosphorus hath  
 “ made its appearance, its contents may be saved  
 “ by throwing a number of cold bricks into the  
 “ fire-place, and upon them a little water to  
 “ quench the fire at once.” All these useful ob-  
 servations we owe also to M. Hellot.

The Phosphorus here described was first discovered by a citizen of Hamburgh named Brandt, who worked upon urine in search of the Philosopher's stone. Afterwards two other skilful Chymists, who knew nothing more of the process than that Phosphorus was obtained from urine, or in general from the human body, likewise endeavoured to discover it; and each of them separately did actually make the discovery. These two Chymists were Kunckel and Boyle.

The former perfected the discovery, and found out a method of making it in considerable quantities at a time; which occasioned it to be called *Kunckel's Phosphorus*. The other, who was an English gentleman, had not time to bring his discovery to perfection, and contented himself with lodging a voucher of his having discovered it in the hands of the Secretary of the Royal Society of London, who gave him a certificate thereof.

“ Though Brandt, says M. Hellot, who had before this sold his secret to a Chymist named  
 “ Krafft, sold it afterwards to several other persons, and even at a very low rate; and though  
 “ Mr.



“ Mr. Boyle published the process for making it ;  
 “ yet it is extremely probable that both of them  
 “ kept in their own hands the master-key ; I  
 “ mean, *the particular management necessary to make*  
 “ *the operation succeed* : for till Kunckel found it  
 “ out, no other Chymist ever made any consider-  
 “ able quantity thereof, except Mr. Godfrey  
 “ Hankwitz, an English Chymist, to whom Mr.  
 “ Boyle revealed the whole mystery.

“ Nevertheless, continues he, we are very far  
 “ from alledging that all those who have described  
 “ this operation meant to impose upon the world :  
 “ but we conceive that most of them having ob-  
 “ served luminous vapours in the ballon, and some  
 “ sparks about the juncture of the vessels, were  
 “ contented with those appearances. And thus it  
 “ came to pass, that, after Kunckel and Boyle  
 “ died, Mr. Godfrey Hankwitz was the only Chy-  
 “ mist that could supply Europe therewith ; on  
 “ which account it is likewise very well known  
 “ by the name of *English Phosphorus*.”

Almost all the Chymists consider Phosphorus as a substance consisting of the Acid of Sea-salt combined with the Phlogiston, in the same manner as Sulphur consists of the Vitriolic Acid combined with the Phlogiston. This opinion is founded on the following principles.

First, Urine abounds with Sea-salt, and contains also a great deal of Phlogiston : now these are the ingredients of which they conjecture Phosphorus to be composed.

Secondly, Phosphorus has many of the properties of Sulphur ; such as being soluble in oils ; melting with a gentle heat ; being very combustible ; burning without any soot ; giving a vivid and bluish flame ; and lastly, leaving an acid liquor when burnt : sensible proofs that it differs from Sulphur in nothing but the nature of its Acid.

Thirdly,

Thirdly, this Acid of Phosphorus, being mixed with a solution of silver in Spirit of Nitre, precipitates the silver, and this precipitate is a true *Luna cornea*, which appears to be more volatile even than the common sort; as M. Hellot tells us, who made the experiment. This fact proves incontestably that the Acid of Phosphorus is of the same nature with that of Sea-salt: for all Chymists know that the property of precipitating silver in a *Luna cornea* belongs to the Marine Acid only.

Fourthly, M. Stahl observes that, if Sea-salt be cast on live coals, they instantly burn with great activity; then they emit a very vivid flame, and are much sooner consumed than if none of this Salt had touched them; that Sea-salt in substance, which will bear the violence of fire a considerable time when fused in a crucible, without sustaining any sensible diminution, yet evaporates very quickly, and is reduced to white flowers, by the immediate contact of burning coals; and lastly, that the flame which rises on this occasion is of a blue colour inclining to violet, especially if it be not thrown directly on the coals themselves, but kept in fusion amidst burning coals, in a crucible so placed that the vapour of the Salt may join with the enflamed Phlogiston as it rises from the coals.

These experiments of Mr. Stahl's prove that the Phlogiston acts upon the Acid of Sea-salt, even while it is combined with its alkaline basis. The flame that appears on this occasion may be considered as an imperfect Phosphorus: and indeed its colour is exactly like that of Phosphorus.

All the facts above related evince that the Acid of Phosphorus is akin to that of Sea-salt; or rather that it is the very same. But there are other facts which prove that this Acid undergoes some change at least, some peculiar preparation, before it enters into the composition of a true Phosphorus, and that,

when

when extricated therefrom by burning, it is not a pure Acid of Sea-salt, but is still adulterated with a mixture of some other substance, which makes it considerably different from that Acid. For these observations we are obliged to M. Marggraff, of the Academy of Sciences at Berlin, a celebrated Chymist. I shall presently give an account of his principal experiments as succinctly as possible.

M. Marggraff hath also published a process for making Phosphorus, and assures us that by means thereof we may obtain in less time, with less heat, less trouble, and less expence, a greater quantity of Phosphorus than by any other method. His operation is this :

He takes two pounds of Sal Ammoniac in powder, which he mixes accurately with four pounds of Minium. This mixture he puts into a glass retort, and with a graduated fire draws off a very sharp, volatile, urinous spirit.

We observed in our theoretical Elements that some metallic substances have the property of decomposing Sal Ammoniac, and separating its volatile Alkali; concerning which phenomenon we here gave our opinion. Minium, which is a calx of lead, is one of those metallic substances. In this experiment it decomposes the Sal Ammoniac, and separates its volatile Alkali; what remains in the retort is a combination of the Minium with the Acid of the Sal Ammoniac, which is well known to be the same with the Marine Acid; and consequently the residue of this operation is a sort of *Plumbum corneum*.

The quantity thereof is four pounds eight ounces. Of this he mixes three pounds with nine or ten pounds of urine, that has stood putrefying for two months, evaporated to the consistence of honey. These he mixes by little and little in an iron pan over the fire, stirring the mixture from time to time. Then he adds half a pound of charcoal dust, and



evaporates the matter, kept continually stirring, till the whole be brought to a black powder. He next distils the mixture in a glass retort with degrees of fire, which he raises towards the end so as to make the retort red-hot, in order to expel all the urinous spirit, superfluous oil, and ammoniacal salt. The distillation being finished, there remains nothing in the retort but a very friable *caput mortuum*.

This remainder he pulverises again, and throws a pinch thereof on live coals, thereby to discover whether or no the matter be rightly prepared, and in order, for yielding Phosphorus. If it be so, it presently emits an arsenical odour, and a blue undulating flame, which passes over the surface of the coals like a wave.

Being thus assured of the success of his operation, he puts one half of his matter, in three equal parts, into three small earthen German retorts, capable of holding about eighteen ounces of water a-piece. These three retorts, none of which is above three quarters full, he places together in one reverberatory furnace, built much like those we have described, except that it is so constructed as to hold the three retorts disposed in one line. To each retort he lutes a recipient something more than half full of water, ordering the whole in such a manner, that the noses of his retorts almost touch the surface of the water.

He begins the distillation with warming the retorts slowly, for about an hour, by a gentle heat. When that time is elapsed he raises the fire gradually, so that in half an hour more, the coals begin to touch the bottoms of the retorts. He continues throwing coals into the furnace by little and little, till they rise half way the height of the retorts; and in this he employs another half hour. Lastly, in the next half hour he raises the coals above the bowls of the retorts.

Then the Phosphorus begins to ascend in clouds on this he instantly increases the heat of the fire a  
much

much as possible, filling the furnace quite up with coals, and making the retorts very red. This degree of fire causes the Phosphorus to distil in drops which fall to the bottom of the water. He keeps up this intense heat for an hour and half, at the end of which the operation is finished; so that it lasts but four hours and a half in all: nay, he further assures us that an artist, well versed in managing the fire, may perform it in four hours only. In the same manner he distils the second moiety of his mixture in three other such retorts.

The advantage he finds in making use of several small retorts, instead of a single large one, is that the heat penetrates them with more ease, and the operation is performed with less fire, and in less time. He purifies and moulds his Phosphorus much in the same manner as M. Hellot does. From the quantity of ingredients above-mentioned, he obtains two ounces and a half of fine crystalline moulded Phosphorus.

M. Marggraff considering, as a consequence of the experiments above related, that a highly concentrated Acid of Sea-salt contributes greatly towards the formation of Phosphorus, proceeded to try several other experiments, in which he employed that Acid in a state of combination with other bases. He mixed, for instance, an ounce of *Lunarnea* with an ounce and half of putrefied and inspissated urine, and from the mixture obtained a very beautiful Phosphorus.

In short, the several experiments mentioned having thoroughly persuaded him that the Acid of sea-salt, provided it were highly concentrated, could combine with the Phlogiston as readily as the Vitriolic Acid does, he resolved to try whether he could not make Phosphorus with matters containing that Acid and the Phlogiston, without making use of any urine.

With this view he made a great number of different trials, wherein he employed Sea-salt in substance, Sal Ammoniac, Plumbum corneum, Luna cornea, fixed Sal Ammoniac, otherwise called *Oil of Lime*. These several substances, all of which contain the Acid of Sea-salt, he mixed with sundry matters abounding in Phlogiston, different vegetable coals, and even animal matters, such as the oil of hartshorn, human blood, &c. varying the proportions of these substances many different ways, without ever being able to produce a single atom of Phosphorus: which gave this able Chymist just cause to suspect that the Marine Acid, while pure and crude, is not capable of combining with the Phlogiston in the manner requisite to form a Phosphorus; that for this purpose it is necessary the Acid should have contracted a previous union with some other matter; and that the Acid found in urine hath probably undergone the necessary change. M. Marggraff is of opinion that the matter, which by its union renders the Marine Acid capable of entering into the composition of Phosphorus, is a sort of exceedingly subtile vitrifiable earth. The experiments he made upon the Acid of Phosphorus will shew that his notion is not altogether groundless. M. Marggraff having let some urine, evaporated to the consistence of honey, stand quiet in a cool place, obtained from it, by crystallization, Salt of a singular nature. By distilling this urine afterwards, he satisfied himself that it yielded him much less Phosphorus than urine from which no Salt had been extracted; and as it cannot be entirely deprived of this Salt, he thinks that the final quantity of Phosphorus, which this urine yielded him, came from the Salt that was still left in it.

Further, he distilled this Salt separately with lamp-black, and obtained from it a considerable quantity of very fine Phosphorus. He even mixe



*Lana cornea* with this Salt, in order to see whether it would not increase the quantity of his Phosphorus; but without success: whence he concluded, that in this Saline matter resides the true Acid that is fit to enter into the composition of Phosphorus. This opinion is confirmed by several experiments on the Acid of Phosphorus, which he found to have some properties resembling those of this Salt.

The Acid of Phosphorus seems to be more fixed than any other: and therefore if you would separate it, by burning, from the Phlogiston with which it is united, there is no occasion for such an apparatus of vessels as is employed for obtaining the Spirit of Sulphur. For this Acid will remain at the bottom of the vessel in which you burn your Phosphorus: indeed, if it be urged by the force of fire, its most subtile part evaporates, and the remainder appears in the form of a vitrified matter.

This Acid effervesces with fixed and volatile Alkalis, and therewith forms Neutral Salts; but very different from Sea-salt, and from Sal-Ammoniac. That which has a fixed Alkali for its basis does not crackle when thrown on burning coals, but swells and vitrifies like Borax. That which has a volatile Alkali for its basis shoots into long pointed crystals; and, being urged by fire in a retort, lets go its volatile alkali, a vitrified matter remaining behind. This Salt is like that above-mentioned, as obtained from urine and yielding Phosphorus.

It appears from the experiments adduced, that the Acid of Phosphorus tends always to vitrification; which proves that it is not pure, and gave M. Marggraff cause to think that it is altered by the admixture of a very subtile vitrifiable earth.

M. Marggraff also obtained Phosphorus from several vegetable substances which we use every day for food. This gives him occasion to conjec-

ture that the Salt requisite to the formation of Phosphorus exists in vegetables, and passes from thence into the animals that feed upon them.

Lastly, he concludes his dissertation by informing us of a very important truth, viz. That the Acid obtained from Phosphorus, by burning it, will serve to form Phosphorus anew; for which purpose it need only be combined with some charred coal, such as lamp-black, and distilled.

From what hath been said on this subject it is plain the Chymists have a great many curious and interesting enquiries to make concerning Phosphorus, and particularly concerning its Acid.

I shall conclude this article with an account of certain properties of Phosphorus which I have not yet mentioned.

Phosphorus dissolves by lying exposed to the air. What water cannot effect, says M. Hellot, or at least requires eight or ten years to bring about, the moisture of the air accomplishes in ten or twelve days; whether it be that the Phosphorus takes fire in the air, and the inflammable part evaporating, almost entirely, leaves the Acid of the Phosphorus naked, which like all other Acids, when exceedingly concentrated, is very greedy of moisture; or else into infinitely fine particles, is so subtil as to find its way through the pores of the Phosphorus, into which the grosser particles of common water can by no means insinuate themselves.

Phosphorus heated by the vicinity of fire, or by being any way rubbed, soon takes fire and burns fiercely. It is soluble in all Oils and in Ether, giving to those liquors the property of appearing luminous when the bottle containing the solution is opened. Being boiled in water, it likewise communicates thereto this luminous quality. M. Morin, Professor at Chartres, is the author of this observation.

The

The late Mr. Grosse, a celebrated Chymist, of the Academy of Sciences, observed that Phosphorus being dissolved in essential oils crystallizes therein. These crystals take fire in the air, either when thrown into a dry vessel, or wrapt up in a piece of paper. If they be dipped in Spirit of Wine, and taken out immediately, they do not afterwards take fire in the air: they smoke a little, and for a very short time, but hardly waste at all. Though some of them were left in a spoon for a fortnight, they did not seem to have lost any thing of their bulk: but when the spoon was warmed a little they took fire, just like common Phosphorus that had never been dissolved and crystallized in an essential oil.

M. Marggraff, having put a dram of Phosphorus with an ounce of highly concentrated Spirit of Nitre into a glass retort, observed that, without the help of fire, the Acid dissolved the Phosphorus; that part of the Acid came over into the recipient which was luted to the retort; that at the same time the Phosphorus took fire, burnt furiously, and burst the vessels with explosion. Nothing of this kind happens when any of the other Acids, though concentrated, are applied to Phosphorus.

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### P R O C E S S III.

*To decompose Sea-Salt by means of the Vitriolic Acid.  
Glauber's Salt. The Purification and Concentration of Spirit of Salt.*

**P**UT the Sea-salt from which you mean to extract the Acid into an unglazed earthen pipkin, and set it amidst live coals. The Salt will decrepitate, grow dry, and fall into a powder. Put this decrepitated Salt into a tubulated glass retort, leaving two thirds thereof empty. Set the retort in a reverberating furnace; apply a receiver like that



used in distilling the smoking Spirit of Nitre, and lute it on in the same manner; or rather more exactly if possible. Then through the hole, in the upper convexity of the retort, pour a quantity of highly concentrated Oil of Vitriol, equal in weight to about a third part of your Salt, and immediately shut the hole very close with a glass stopple, first ground therein with emery so as to fit it exactly.

As soon as the Oil of Vitriol touches the Salt, the retort and receiver will be filled with abundance of white vapours; and soon after, without lighting any fire in the furnace, drops of a yellow liquor will distil from the nose of the retort. Let the distillation proceed in this manner without fire, as long as you perceive any drops come: afterwards kindle a very small fire under the retort, and continue distilling and raising the fire by very slow degrees, and with great caution, to the end of the distillation; which will be finished before you have occasion to make the retort red-hot. Unlute the vessels, and without delay pour the liquor, which is a very smoking Spirit of Salt, out of the receiver into a crystal bottle, like that directed for the smoking Spirit of Nitre.

### OBSERVATIONS.

SEA-SALT, as hath been already said, is a Neutral Salt composed of an Acid, which differs from those of Vitriol and Nitre, combined with a Fixed Alkali that has some peculiar properties; but does not vary from the others in its affinities. This Salt therefore, as well as Nitre, must be decomposed by the Vitriolic Acid; which accordingly is the case in the process here described. The Vitriolic Acid unites with the Alkaline basis of the Sea-salt, and separates its Acid; and that with much greater facility than it expels the Nitrous Acid from its Alkaline

line basis, because the Acid of Sea-Salt has not so great an affinity as the Nitrous Acid with Fixed Alkalis.

As a highly concentrated Oil of Vitriol is used on this occasion, and as the Sea-salt is previously dried and decrepitated, the Acid obtained from it by distillation is very free from phlegm, and always smokes, even more violently than the strongest Acid of Nitre. The vapours of this Acid are also much more elastic and more penetrating than those of the Nitrous Acid: on which account this distillation of the smoking Spirit of Salt is one of the most difficult, most laborious, and most dangerous operations in Chymistry.

This process requires a tubulated retort, that the Oil of Vitriol may be mixed with the Sea-salt after the receiver is well luted to the retort, and not before: for, as soon as these two matters come together, the Spirit of Salt rushes out with so much impetuosity, that, if the vessels were not luted at the time, the copious vapours that would issue through the neck of the ballon would so moisten it, as well as the neck of the retort, that it would be impracticable to apply the lute and secure the joint as the operation requires. Moreover, the operator would be exposed to those dangerous fumes, which, on this occasion, rush out, and enter the lungs, with such incredible activity as to threaten instant suffocation.

Having said so much of the elasticity and activity of the fumes of Spirit of Salt, it is needless to insist upon the necessity of giving vent to the vessels from time to time, by opening the little hole of the ballon: indeed the best way to prevent the loss of a great many vapours, on this occasion, is to employ adopters, and cover them with wet canvas, which will cool and condense the vapours they contain.

When the operation is finished, we find a white, saline mass at the bottom of the retort as in a mould. If this mass be dissolved in water, and the solution

crystal-

crystallized, it yields a considerable quantity of Sea-salt that hath not been decomposed, and a Neutral Salt consisting of the Vitriolic Acid united with the Alkaline basis of that part which hath been decomposed. This Neutral Salt, which bears the name of *Glauber* its inventor, differs from Vitriolated Tartar, or the *Sal de duobus*, which remains after distilling the Nitrous Acid, especially in that it is more fusible, more soluble in water, and hath its crystals differently figured. But as in these two Salts the Acid is the same, the differences that appear between them must be attributed to the peculiar nature of the basis of Sea-salt.

Spirit of Salt drawn by the process above described is tainted with a small mixture of the Vitriolic Acid, carried up by the force of fire before it had time to combine with the Alkali of the Sea-salt; which happens likewise to the Nitrous Acid procured in the same manner. If you desire to have it pure, and absolutely free from the Acid of Vitriol, it must be distilled a second time from Sea-salt, as the Acid of Nitre was before directed to be distilled again from fresh Nitre, in order to purify it from any Vitriolic taint.

Sea-salt, as well as Nitre, may be decomposed by any combination of the Vitriolic Acid with a metallic or earthy substance: but it is proper to observe, that if you distil Spirit of Salt by means of Green Vitriol, the operation will not succeed so well as when Spirit of Nitre is distilled in the same manner: less Spirit is obtained, and a much fiercer fire is required.

The cause of this lies in the property which the Acid of Sea-salt possesses of dissolving Iron, even when deprived of a part of its Phlogiston by having contracted an union with another Acid; so that it is no sooner dislodged from its own basis by the Vitriolic Acid, than it unites with the ferruginous basis



basis of the Vitriol, from which it cannot be separated but by a most violent fire. This is the consequence more especially when calcined Vitriol is made use of: for moisture, as we shall presently see, greatly facilitates the separation of the Marine Acid from those substances with which it is united.

When you do not desire a highly dephlegmated and smoking Spirit of Salt, you may distil with the additament of any earth containing the Vitriolic Acid; as Clay, for instance, or Bole. To this end one part of Sea-Salt, slightly dried and reduced to a fine powder, must be accurately mingled with two parts of the earth you intend to employ likewise pulverized; of this mixture make a stiff paste with a proper quantity of rain water, and having formed little balls about the size of a hazel nut, let them dry in the sun; when dry put them into a stone or coated glass retort, leaving a third part thereof empty; set this vessel in a reverberating furnace, covered with its dome; apply a receiver, which need not be luted on for some time; and heat the vessels very slowly. At first an insipid water will rise; which must be thrown away: afterwards the Spirit of Salt will appear in white clouds. Now lute your vessels, and raise the fire by degrees; which towards the end must be pushed to the utmost extremity. The operation is known to be finished when no drops fall from the nose of the retort, the receiver cools, and the white vapours that filled it are seen no more.

The Spirit of Salt obtained by the process here delivered does not smoke, and contains much more phlegm than that which is distilled by means of the concentrated Oil of Vitriol; because the earth, though dried in the sun, still retains a great deal of moisture, which commixes with the Acid of the Sea-salt. Consequently it is much easier to collect its vapours; so that this operation is attended with  
much

much less trouble than the other. Nevertheless it is adviseable to proceed gently; to apply but little heat at first, and to unstop every now and then the small hole of the receiver: for a quantity of the vapours of Spirit of Salt, even when weakened by the admixture of water, is very apt to burst the vessels.

A much greater degree of fire is necessary to raise the Spirit of Salt by this latter process, than by that in which the pure Vitriolic Acid is employed: for, as fast as the Spirit of Salt is dislodged from its own basis, by the Vitriolic Acid contained in the earth made use of, part of it joins that earth, and cannot be separated from it without the most violent heat.

A Spirit of Salt that shall not smoke may also be obtained by means of the pure Vitriolic Acid. Spirit of Vitriol, or Oil of Vitriol, lowered with a good deal of water, will do the business.

Some Chymists direct a little water to be placed in the receiver, when Spirit of Salt is to be distilled by the intermedium of concentrated Oil of Vitriol, in order to make the acid vapours condense more readily. By this means indeed some of the inconveniencies attending the distillation of smoking Spirit of Salt may be avoided: but on the other hand, the acid vapours being absolutely suffocated by the water as fast as they come over, the Spirit of Salt obtained by this method will be no less aqueous than that procured by the interposition of earths: so that here is an expence to no manner of purpose. Therefore, when a Spirit of Salt is desired that shall not smoke, it is best to employ an additament of earth; and that so much the rather, as the Marine Acid obtained by this means is purer and freer from any Vitriolic taint, for the reasons already assigned.

Part of the Acid of Sea-salt may be separated from its Alkaline basis by the force of fire alone, without the intervention of any other body. With  
this

this view the Salt must be put into the retort without being dried. At first an insipid water rises; but it gradually becomes acid, and hath all the properties of spirit of Salt. When the Salt in the retort is grown perfectly dry, nothing more can be forced over by any degree of heat whatever. If you would obtain more Acid from the same Salt, you must take it out of the retort, where you will find it in a lump, reduce it to powder, and expose it to the air for some time, that it may attract the moisture thereof; or else wet it at once with some rain water, and distil as before. You will again have an insipid water, and a little Spirit of Salt; which will in like manner cease to rise when the Salt in the retort becomes dry. This operation may be repeated as often as shall be thought proper: and perhaps it may be possible to decompose Sea-salt entirely by means thereof, without the interposition of any other body. The Spirit of Salt thus obtained is exceeding weak, in small quantity, and loaded with much water.

This experiment proves that moisture greatly facilitates the separation of the Acid of Sea-salt from the matters with which it is united: and this is the reason that, in distilling Spirit of Salt with the aditament of an earth, the operation requires much less fire at the beginning, while the earth and salt retain a great deal of humidity, than towards the end, when they begin to grow dry.

After the operation there remains in the retort a saline and earthy mass, which contains, 1. Some entire Sea-salt that has suffered no decomposition; 2. A Glauber's Salt which is, as we said before, a Neutral Salt consisting of the Vitriolic Acid united with the Alkaline basis of the Sea-salt, from which it hath expelled its proper Acid; 3. Part of the earth used as an intermedium, still retaining a portion of its original Vitriolic Acid, which, happening not to lie near enough to any particles of Sea-salt, could



could not exert its power in decomposing them, and so remains united with its earthy basis; 4. Another part of the same earth, impregnated with some of the Marine Acid, which combined therewith upon being expelled from its Alkaline basis by the Vitriolic Acid, and which the force of fire was unable to separate from it when the matters were grown perfectly dry. In consequence of what remains in this *caput mortuum*, if the whole mass be triturated, moistened with a little water, and distilled a second time, considerably more Spirit of Salt will be obtained from it: and the same is to be said of all distillations of this sort.

Spirit of Salt obtained by the means of any other additament than concentrated Oil of Vitriol is generally very weak: but it may be dephlegmated and concentrated, if required, much in the same manner as Oil of Vitriol. For this purpose you must put it into a glass cucurbit, set it in a *balneum mariæ*, fit thereto a head and a receiver, and with a moderate degree of heat draw off one third or one half of the liquor. What comes over into the receiver will be the most aqueous part, which being the lightest will rise first, impregnated however with a little acid: in the cucurbit will be left a concentrated Spirit of Salt, or the most acid part; which being the heaviest will not rise with the degree of heat that is capable of carrying up the phlegm. Spirit of Salt thus concentrated, called also *Oil of Salt*, does not smoke: it is of a yellow colour inclining to green, and an agreeable smell, not unlike that of saffron.

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#### P R O C E S S IV.

*To decompose Sea-salt by means of the Nitrous Acid.*  
*Aqua regis. Quadrangular Nitre.*

**T**AKE dried Sea-salt: bruise it to powder: put it into a glass-retort, leaving one half of the vessel empty. Pour upon it a third of its weight  
of

of good Spirit of Nitre. Place your retort in the sand-bath of a reverberating furnace; put on the dome; lute to the retort a receiver having a small hole in it, and heat the vessels very slowly. There will come over into the receiver some vapours, and an acid liquor. Increase the fire gradually till nothing more rises. Then unlute the vessels, and pour the liquor out of the receiver into a crystal bottle, stopped like others containing Acid Spirits.

## OBSERVATIONS.

THE Nitrous Acid hath a greater affinity than the Marine Acid with Fixed Alkalis. When therefore Spirit of Nitre and Sea-salt are mixed together, the same consequences, in some measure, will follow, as when the Vitriolic Acid is mixed with that Salt; that is, the Nitrous Acid will, like the Vitriolic, decompose it, by dislodging its Acid from its Alkaline basis, and assuming its place. But as the Nitrous Acid is considerably weaker, and much lighter, than the Vitriolic Acid; a good deal of it rises along with the Acid of Sea-salt during the operation. The liquor found in the receiver is therefore a true *Aqua regis*.

If decrepitated Salt, and a right smoking Spirit of Nitre, be employed in this process, the *Aqua regis* obtained will be very strong; and during the operation very elastic vapours will rush out and burst the vessels, if those precautions be not taken which we pointed out as necessary in distilling the Spirit of Nitre, and the smoking Spirit of Salt.

The operation being finished, there is left in the retort a saline mass, containing Sea-salt not decomposed, and a new species of Nitre, which having for its basis the Alkali of Sea-salt, that is, as we have several times observed, an Alkali of a peculiar nature, differs from the common Nitre, 1. In the figure of its crystals; which are solids of four sides, formed

formed liked lozenges: 2. In that it cryftallizes with more difficulty. retains more water in its cryftals, attracts the moiſture of the air, and diſſolves in water with the ſame circumſtances as Sea-falt.

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## CH A P. IV.

### Of B O R A X,

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## P R O C E S S IV.

*To decompoſe Borax by the means of Acids; and to ſeparate from it the Sedative Salt by ſublimation and by cryſtallization.*

**R**EDUCE to a fine powder the Borax from which you intend to extract the Sedative Salt. Put this powder into a wide-necked glaſs retort. Pour upon it an eighth part of its weight of common water, to moiſten the powder; and then add concentrated Oil of Vitriol, to the weight of ſomewhat more than a fourth part of the weight of the Borax. Set the retort in a reverberatory, make a moderate fire at firſt, and augment it gradually till the retort become red-hot.

A little phlegm will firſt come over, and then with the laſt moiſture that the heat expels the Sedative Salt will riſe; by which means ſome of it will be diſſolved in this laſt phlegm, and paſs therewith into the receiver; but moſt of it will adhere in the form of ſaline flowers to the fore-part of the neck of the retort, juſt where it is clear of the groove of the furnace. There they collect into a heap, which the ſucceeding flowers push inſenſibly forward till they ſlightly ſtop the paſſage. Thoſe which riſe after the neck is thus ſtopped ſtick to the after-part of it which is hot, vi-

trify



tify in some measure, and form a circle of fused Salt. In this state the flowers of the Sedative Salt seem to issue out of the circle; as from their basis: they appear like very thin, light, shining scales, and must be brushed off with a feather.

At the bottom of the retort will be left a saline mass: dissolve this in a sufficient quantity of hot water; filter the solution in order to free it from a brown earth which it deposes; set the liquor to evaporate, and crystals of Sedative Salt will form in it.

### OBSERVATIONS.

THOUGH Borax is of great use in many chymical operations, especially in the fusion of metals, as we shall have occasion to see, yet till of late years Chymists were quite ignorant of its nature, as they still are of its origin; concerning which we know nothing with certainty, but that it comes rough from the East Indies, and is purified by the Dutch.

M. Homberg was one of the first that attempted to analyse this Salt. He shewed that on mixing it with the Vitriolic Acid, and distilling the mixture, a salt sublimes in little fine needles. This product of Borax he called by the name of *Sedative Salt*, because he found it had the property of moderating the great tumult and heat of the blood in fevers.

After M. Homberg other Chymists also exercised themselves on Borax. M. Lemery discovered that the Vitriolic is not the only Acid by means of which the Sedative Salt may be obtained from Borax; but that either of the other two Mineral Acids, the Nitrous or the Marine, may be used in its stead.

M. Geoffroy hath greatly facilitated the means of obtaining the Sedative Salt from Borax; having shewn that it may be extracted by crystallization as well as by sublimation; and that the Sedative Salt

so obtained is in no respect inferiour to that which was procured before by sublimation only. To him also we are indebted for the discovery that in the composition of Borax there is an Alkaline Salt of the same nature as the basis of Sea-salt. This he found by observing that he got a Glauber's Salt from a solution of Borax into which he had poured some Vitriolic Acid with a view to obtain its Sedative Salt.

Lastly, M. Baron, whom we mentioned before on occasion of this Salt, hath proved, by a great number of experiments, that a Sedative Salt may be procured from Borax by the help of Vegetable Acids, which was never done by any body before him; that the Sedative Salt is not a combination of an Alkaline matter with the Acid made use of in extracting it, as some of its properties seemed to indicate; but that it exists previously and completely formed in the Borax; that the Acid employed to extract it only helps to disengage it from the Alkali with which it is united; that this Alkali is actually of the same nature as the basis of Sea-salt, because that after extracting the Sedative Salt, which by its union therewith forms the Borax, a Neutral Salt is found, of the same sort with that which would be produced by combining the basis of Sea-salt with the particular Acid made use of; that is, if with the Vitriolic Acid, a Glauber's salt; if with the Nitrous Acid, a quadrangular Nitre; and if with the Marine Acid, a true Sea-salt; and lastly, that the Sedative Salt may be re-united to its Alkali, and re-produce a Borax.

Nothing therefore now remains, to give us all the insight we can desire into the nature of Borax, but to know what the Sedative Salt is. M. Baron hath already given us certain negative notices concerning it, by shewing what it is not; that is, that the Acid employed in its extraction doth not enter into its composition. We have great reason to hope

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that he will carry his enquiries still further, and clear up all our doubts on this subject.

The Sedative Salt may be extracted from Borax, not only by the means of pure and simple Acids, but also by the same Acids combined with a metallic basis. Thus Vitriols, for instance, may be employed for this purpose with good success. It is easy to see that the Vitriol must be decomposed on this occasion, and that its Acid cannot unite with the Alkali in which the Sedative Salt is lodged, without quitting its metallic basis, which must of course precipitate.

The Sedative Salt actually sublimes, when a liquid containing it is distilled; but it does not therefore follow that it is naturally volatile. It rises only by the aid of the water with which it is mixed. The proof of this assertion is, that, when all the humidity of the mixture containing this Salt is dissipated, no more Salt will rise, be the fire ever so violent; and that by adding more water to moisten the dried mass containing it, more Salt will every time be obtained, through many repeated distillations. In the same manner, if some Sedative Salt be moistened, and exposed to a proper degree of heat, a small quantity thereof will rise at first by the help of the water; but as soon as it grows dry it remains exceedingly fixed. This observation we owe to M. Rouelle.

The Sedative Salt hath the appearance and the taste of a Neutral Salt: it does not change the colour of the juice of violets; nor does it easily dissolve in water; for it requires a quart of boiling water to dissolve two ounces of it: yet, with regard to Alkalis, it has the properties of an Acid; it unites with those salts, forms therewith a saline compound which crystallizes, and even expels the Acids that happen to be combined with them; so that it decomposes the same Neutral Salts that are decomposed by the Vitriolic Acid.



The Sedative Salt, when suddenly exposed to the violent heat of a naked fire, loses near half its weight, melts, puts on and retains the appearance of glass; but its nature still remains unchanged. This glass dissolves in water, and shoots anew into crystals of Sedative Salt. This Salt communicates to the Alkaline salt with which it is united, when in the form of Borax, the property of melting with a moderate heat, and forming a kind of glass; and 'tis this great fusibility that recommends the frequent use of Borax as a flux for assaying ores. It is also employed sometimes as an ingredient in the composition of glass; but, in time, it always communicates thereto the fault which its own glass hath, namely, that of tarnishing with the air. The Sedative Salt hath moreover the singular property of dissolving in Spirit of Wine, and of giving to its flame, when set on fire, a beautiful green colour. All these observations we owe to Mess<sup>rs</sup>. Geoffroy and Baron.

M. Geoffroy prepares the Sedative Salt by crystallization only, in the following manner. “ He  
 “ dissolves four ounces of refined Borax in a sufficient quantity of warm water, and then pours  
 “ into the solution one ounce and two drams of  
 “ highly concentrated Oil of Vitriol, which makes  
 “ a crackling noise as it falls in. When this mixture has stood evaporating for some time, the  
 “ Sedative Salt begins to make its appearance in  
 “ little, fine, shining plates, floating on the surface of the liquor. The evaporation is then to  
 “ be stopped, and the plates will by little and little  
 “ encrease in thickness and breadth. They unite  
 “ together into little tufts, forming with each  
 “ other sundry different groups. If the vessel be  
 “ ever so little stirred, the regularity of the crystals  
 “ will be disturbed; so that it must not be touched  
 “ till the crystallization appears to be finished.

“ The

“ The crystalline clusters, being grown too bulky  
 “ and too heavy, will then fall of themselves to  
 “ the bottom of the vessel. This being observed,  
 “ the saline liquor must be gently decanted from  
 “ those little crystals, which, as they are not easily  
 “ dissolved, must be washed clean, by pouring cold  
 “ water slowly on the sides of the pan, three or four  
 “ times successively, in order to rinse out all re-  
 “ mains of the saline liquor, and then set first to  
 “ drain, and afterwards to dry in the sun. This  
 “ Salt, in the form of light flakes of snow, is now  
 “ soft to the touch, cool in the mouth, slightly  
 “ bitter, crackling a little between the teeth, and  
 “ leaving a small impression of acidity on the  
 “ tongue. It will keep long without giving or  
 “ calcining, if managed according to the preced-  
 “ ing directions; that is, if it be exactly freed  
 “ from its saline liquor.

“ It differs from the Sedative Salt obtained by  
 “ sublimation in this respect only, that notwith-  
 “ standing its seeming lightness it is a little heavier  
 “ than the other. M. Geoffroy supposes the cause  
 “ of this weight to be, that, as several of the thin  
 “ plates adhere together in crystallizing, they re-  
 “ tain between them some small matter of humi-  
 “ dity; or, if you will, that, as they form larger  
 “ crystals, they present less surface to the air which  
 “ elevates light bodies: whereas, on the contrary,  
 “ the other Sedative Salt, being driven up by the  
 “ force of fire, rises into the head of the cucurbit  
 “ in a more subtile form, having its particles much  
 “ more expanded and divided.

“ M. Geoffroy, having put his Sedative Salt  
 “ made by crystallization to all the same trials with  
 “ that made by sublimation, satisfied himself that  
 “ there is no other difference between the two.  
 “ If the Sedative Salt made by crystallization hap-  
 “ pens to calcine in the sun; that is, if its lustre

“ tarnishes, and its surface grows mealy, 'tis a sign  
“ that it still contains either a little Borax or some  
“ Glauber's Salt: for these two Salts are apt to  
“ calcine in this manner, and pure Sedative Salt  
“ should not be subject to this inconvenience. In  
“ order to purify it, and free it entirely from those  
“ Salts, it must be dissolved once more in boiling  
“ water. As soon as the water cools, the Sedative  
“ Salt re-appears in light, shining, crystalline  
“ plates, swimming in the liquor. After stand-  
“ ing four-and-twenty hours, the liquor must be  
“ decanted, and the salt washed with fresh water;  
“ by which means it will be very pure and  
“ beautiful.”

Glauber's Salt and Borax dissolve in water with vastly more ease than the Sedative Salt, and consequently do not crystallize so readily by much: so that the small portion of those salts, which may have been left on the surface of the Sedative Salt, being diffused through a large quantity of water, continues in a state of solution, while the Sedative Salt crystallizes; which being also washed afterwards with fair water, it is impossible that the smallest particle of those other Salts should remain adhering to it; and consequently this must be deemed an excellent way of purifying it.



## SECTION II.

*Of Operations on METALS.*

## CHAP. I.

*Of GOLD.*

## PROCESS I.

*To separate Gold, by Amalgamation with Mercury, from the Earths and Stones with which it is found mixed.*

**P**ULVERIZE the earths and stones containing Gold. Put the powder into a little wooden tray; dip this tray in water, gently shaking it and its contents. The water will grow muddy, by taking up the earthy parts of the ore. Continue washing it in this manner till the water cease to appear turbid. Upon the ore thus washed pour strong vinegar, having first dissolved therein, by the help of heat, about a tenth part of its weight of alum. The powder must be quite drenched and covered with this liquor, and so left to stand for twice twenty-four hours.

Decant the vinegar, and wash your powder with warm water, till the last that comes off hath no taste: then dry it, and put it into an iron mortar, with four times its weight of Quick-silver: triturate the whole with a heavy wooden pestle, till all the powder be of a blackish colour: then pour in a little water, and continue rubbing for some time longer. More earthy and heterogeneous particles will be separated from the metalline parts by means of this

water, which will look dirty: it must then be decanted, and more fair water added. Repeat this several times; then dry what remains in the mortar with a sponge, and by the help of a gentle heat: you will find it an Amalgam of the Mercury with the Gold.

Put this Amalgam into a chamoy bag: tie a knot on its neck, and squeeze it hard between your fingers, over some wide-mouthed vessel; there will issue through the pores of the leather numberless little jets of Mercury, forming a sort of shower, that will collect into large globules in the vessel placed underneath. When you can force out no more Mercury by this means, open the bag, and in it you will find the Amalgam freed from the superfluous Mercury; the Gold retaining only about as much thereof as nearly equals itself in weight.

Put this Amalgam into a glass retort; set this retort in the sand-bath of a reverberating furnace; cover it quite over with sand; apply a glass receiver half full of water, so that the nose of the retort may be under the water. The receiver need not be luted to the retort. Give a gradual heat, and raise the fire till drops of the sublimed Mercury appear in the neck of the retort, and fall into the water with a hissing noise. If you hear any noise in the retort, slacken your fire a little. Lastly, when you observe that, though you raise the fire still higher than before, nothing more will come over, take out your retort, break it, and there you will find the Gold, which must be melted in a crucible with Borax.

### OBSERVATIONS.

Gold is a perfect metal, which can by no means be deprived of its Phlogiston, and on which few, even of the most powerful chymical solvents, have any effect: and therefore it almost always hath its metalline form when found in the earth; from which it may sometimes be separated by simple lotion.

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The Gold dust found in the sands of certain rivers is of this kind. When it resides in stones, or tenacious earths, it may be extracted by the process here delivered; to wit, by Amalgamation, or combination of Mercury with the Gold. Mercury is incapable of uniting with any earthy substances, not even with the metallic earths, when they are deprived of their Phlogiston, and consequently have not the metalline form.

Hence it follows that when Mercury is triturated with particles of Gold, of earth, and of stone, mingled together, it unites with the Gold, and separates it from those heterogeneous matters. Yet, if there be along with the Gold any other metal, in its metalline form, except Iron, the Mercury will amalgamate with that also. This often happens to Silver, which being a perfect metal as well as Gold, is for that reason sometimes dug up in its metalline form, and even incorporated with Gold. When this is the case, the mass that remains in the retort, after abstracting the Mercury of the Amalgama, is a compound of Gold and Silver, which are to be separated from each other by the methods we shall give for that purpose. The present process is therefore applicable to Silver as well as Gold.

Sometimes Gold is intimately combined with such mineral matters as hinder the Mercury from acting upon it. In that case the mixed mass must be roasted before you proceed to Amalgamation: for if the matters be volatile, such, for instance, as antimony or arsenic, the fire will carry them off; so that after roasting, the Amalgamation will succeed. But sometimes these matters are fixed, and require fusion; if so, recourse must be had to some particular methods, which we shall describe when we come to treat of Silver, as these two perfect metals are to be treated in the same manner.

Ores



Ores containing Gold must be washed before an Amalgam is attempted; that the metalline parts, being freed from the numerous particles of earth with which they are encompassed, may the more readily incorporate with the Mercury. Besides, it is the property of Mercury to take the form of a dark unmetallic powder, after being long rubbed with other matters, so that it cannot be easily distinguished from the particles of earth. And hence, if you still continue to grind the matters together, after the Amalgamation is compleated, and wash them again and again, the water that comes off will always look turbid, being impregnated with some particles of the Amalgam. This is easily proved: for if you let the turbid water settle, and distil the sediment, you will obtain Quick-silver from it.

The ore is to be steeped in vinegar charged with alum, in order to cleanse the surface of the Gold, which is often covered with a thin coat of earth that obstructs the Amalgamation.

Great care must be taken that the Mercury employed in this operation be very pure. If it be adulterated with any metallic substance, it must be freed therefrom by the methods which we shall propose in their proper place.

The way of separating Mercury from Gold is founded on the different properties of these two metallic substances; the one being exceedingly fixed, and the other very volatile. The union which Mercury contracts with the metals is not intimate enough, to give the new compound which results therefrom all the properties of either of the two united substances; at least so far as concerns their degrees of fixity and volatility. Hence it comes that, in our Amalgam, the Gold communicates but very little of its fixity to the Mercury, and the Mercury communicates to the Gold but very little of its volatility. Yet if the Mercury be distilled off with a  
much

much greater degree of heat than is necessary to elevate it, a pretty considerable quantity of Gold will most certainly be carried up along with it.

It is also of consequence, on another account, that the fire be duly governed on this occasion. For if too great a degree of heat be applied, and the fire afterwards lowered, the water in the receiver, which covers the nose of the retort, will rise into its body, break it to pieces, and spoil the operation.

The cause of this phenomenon depends on the property which air possesses of rarefying with heat and condensing with cold, joined to its weight. As soon as the retort is acted on by a less degree of heat than acted on it the instant before, the air contained therein is condensed, and leaves a *vacuum*, which the external air, by virtue of its weight, tends to occupy; but, the orifice of the retort being under water, the external air can no way gain admittance, but by pushing in before it the water which intercepts its passage. This caution, as we observed above, must be applied to all distillations, where the vessels are disposed as they are in this.

Care must also be taken that the nose of the retort be not placed too deep under water: for as the neck grows very warm during the operation, because the degree of heat required to raise mercury is about three times greater than that which raises water, it may easily be broken by the contact of the cold water in the receiver.

This method of extracting Gold and Silver from their ores, by Amalgamation with Mercury, is not to be absolutely depended on as a sure proof of the quantity of those metals that may be contained in the earth assayed by this means: for some small part of the Amalgam is always lost in washing it; and moreover, the Mercury, when squeezed through chamoy, always carries with it a small portion of Gold. So that if you desire to know more exactly,

actly, by this method, the quantity of Gold or Silver contained in any earth, the Amalgam must not be squeezed through chamoy, but distilled altogether. Much the surest method of making an accurate assay is that by fusion and scorification, which we shall describe under the head of Silver.

In some countries, and especially in America, the method of Amalgamation is used, for extracting Gold and Silver in large quantities, from the matrices which contain them in their metalline form. Agricola and other metallurgists have described the machines by means whereof such Amalgamations are managed.

## PROCESS II.

*To dissolve Gold in Aqua regis, and by that means to separate it from Silver. Aurum Fulminans. Aurum Fulminans reduced.*

**T**AKE Gold that is perfectly pure, or alloyed with Silver only. Reduce it to little thin plates, by hammering it on an anvil. If it be not sufficiently tough, heat it till it be red in a moderate, clear fire, quite free from smoking coals, and then let it cool gradually, which will restore its ductility.

When the plates are thin enough, make them red hot once more, and cut them into small bits with a pair of sheers. Put these bits into a tall, narrow-mouthed cucurbit, and pour on them twice their weight of good *Aqua regis*, made of one part Sal Ammoniac, or Spirit of Salt, and four parts Spirit of Nitre. Set the cucurbit in a sand-bath moderately heated, stopping its orifice slightly with a paper coffin, to prevent any dirt from falling in. The *Aqua regis* will presently begin to smoke. Round the little bits of Gold will be formed an infinite number of small bubbles, which will rise to the surface



surface of the liquor. The Gold will totally dissolve, if it be pure, and the solution will be of a beautiful yellow colour: if the Gold be alloyed with a small quantity of Silver, the latter will remain at the bottom of the vessel in the form of a white powder. If the Gold be alloyed with much Silver, when the Gold is dissolved the Silver will retain the form of the little metalline plates put into the vessel.

When the dissolution is completed, gently pour off the liquor into another low, wide-mouthed, glass cucurbit, taking care that none of the Silver, which lies at the bottom in the form of a powder, escape with the liquor. On this powder of Silver pour as much fresh *Aqua regis* as will cover it entirely; and repeat this till you are sure that nothing more can be taken up by it. Lastly, having decanted the *Aqua regis* from the Silver, wash the Silver with a little Spirit of Salt weakened with water, and add this Spirit of Salt to the *Aqua regis* in which your Gold is dissolved. Then to the body containing these liquors fit a head and a receiver, and distil with a gentle heat, till the matter contained in the cucurbit become dry.

#### O B S E R V A T I O N S.

It is certain that *Aqua regis* is the true solvent of Gold, and that it does not touch Silver: so that if the Gold dissolved in it were alloyed with Silver, which is often the case, the two metals would by this means be pretty accurately separated from each other. But if you desire to obtain from this solution a Gold absolutely pure, you must free it, before you dissolve it, from every other metallic substance but Silver; because *Aqua regis* acts upon most of the other metals and the semi-metals. We shall shew under the head of Silver, as we promised before, how to purify a mass of Gold and Silver from every other

other metallic alloy. Thither also we refer the common Parting Assay performed by means of *Aqua fortis*: because in that operation the Silver is dissolved, and not the Gold.

If the Gold put to dissolve in *Aqua regis* be pure, the dissolution is easily and readily effected. But if, on the contrary, it be alloyed with Silver, the *Aqua regis* finds more difficulty in dissolving it. Nay, if the Silver exceed the Gold in quantity, the dissolution will not take place at all, for the reasons adduced in our Theoretical Elements; of which we shall speak more fully when we come to treat of the Parting Assay.

In the process we directed the Gold to be dissolved in a tall body. This precaution is necessary to prevent the loss of some part thereof: for it is the property of *Aqua regis* to carry off along with it some of the Gold, especially when there is any Sal Ammoniac in its composition, if the vessel be heated while the dissolution is going on, or if the *Aqua regis* be very strong. Yet it is proper to make use of *Aqua regis* that is too strong rather than too weak: for if it prove too strong, and be observed not to act upon the metal for that reason, it is easy to weaken it, by gradually adding small quantities of pure water, till you perceive it begin to act with vigour. This is a general rule regarding all metallic dissolutions in Acids.

When the solution of Gold is evaporated to dryness, if you desire to reduce into a mass the Gold dust left at the bottom of the cucurbit, you must put it into a crucible, and cover it with pulverized borax, mixed with a little nitre and calcined wine-lees; then cover the crucible close, heat it with a moderate fire, which must be afterwards increased so as to melt the contents. At the bottom of the crucible you will find a lump of Gold, over which the salts you added will be as it were vitrified. These  
salts

salts are added chiefly to promote the fusion of the metal.

The Gold may, if you will, be separated from its solvent without evaporating the solution as above directed. You need only mix with the solution a fixed or volatile Alkali by little and little, till you see no more precipitate fall, and then let the liquor stand to settle, at the bottom of which you will find a sediment: filter the whole, and dry what is left on the filter.

Both fixed and volatile Alkalis possessing, as hath been frequently repeated, a greater affinity with Acids than metallic substances have, they precipitate the Gold, and separate it from the Acids in which it is dissolved: but it is of great consequence to take notice that, if you attempt to melt this precipitated Gold in a crucible, it will fulminate as soon as it feels the heat, with such a terrible explosion, that, if the quantity be at all considerable, it may prove fatal to the operator: even rubbing it a little hard will make it blow up. This preparation is therefore called *Aurum fulminans*.

Hitherto no satisfactory explanation hath been given of this phenomenon. Some Chymists considering that, in the precipitation of the Gold, a Nitre is regenerated by the union of the Alkali with the Nitrous Acid which enters into the composition of the *Aquaregis*, imagine that some of this regenerated Nitre, combining with the precipitated Gold, takes fire and detonates, either by means of some small portion of Phlogiston that may be contained in the Alkali, or by means of that which constitutes the Gold itself. But, in the first place, 'tis well known that Fixed Alkalis do not contain Phlogiston enough to make Nitre detonate. Indeed, if a Volatile Alkali be employed in the precipitation, a Nitrous Ammoniacal Salt will be formed, containing Phlogiston enough  
to



to be capable of detonating without the concurrence of any additional Phlogiston: but this detonation of the Nitrous Ammoniacal Salt is not to be compared, as to the violence of its effects, with the fulmination of Gold. Besides, we do not find that Gold precipitated by a Volatile Alkali explodes with greater force than that precipitated by a Fixed Alkali. As for the Gold, 'tis certain that it suffers no decomposition at all by fulminating. When fulminated under a glass bell, in such small quantities as not to endanger the operator, the Gold is found scattered about under the bell in very fine particles, without having undergone any alteration.

Others have fancied this fulmination of the Gold to be nothing but the decrepitation of the Sea-salt that is regenerated, in the precipitation of the metal, by the Fixed Alkali uniting with the Acid of Sea-salt which makes part of the *Aqua regis*. But to this it may be said, that Gold precipitated by a Volatile Alkali fulminates as violently as that precipitated by a Fixed Alkali; and yet no Sea-salt can be formed in the liquor by the addition of a Volatile Alkali, but only a Sal Ammoniac which has not the property of decrepitating. Moreover, there is no comparison, as to the effects, between the decrepitation of Sea-salt and the fulmination of Gold.

Nor, lastly, can this fulmination be attributed, as it is by some, to the effort made by the Salts to escape from amidst the particles of Gold, in which they are supposed by them to be imprisoned: for then we might deprive this Gold entirely of its fulminating quality by only boiling it in water, and so washing off all the saline particles, which probably adhere to its surface only. It is plain there is great room for very beautiful discoveries on this subject. In Walerius's Mineralogy we find some observations that may throw a little light on the point before us.

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“ The quantity, says he, of fulminating Gold  
 “ precipitated exceeds that of the Gold dissolved :  
 “ if the *Aqua regis* be made with Sal Ammoniac the  
 “ explosion will be stronger ; it will also be more  
 “ violent if the solution be precipitated with a Vo-  
 “ latile Alkali, than if a Fixed Alkali be used for  
 “ that purpose.”

One of the speediest and easiest methods to deprive this Gold of its fulminating quality, is to grind in a mortar twice as much flowers of Sulphur as you have Gold to reduce, mixing your fulminating Gold therewith, by little and little, as you grind them together ; then to put the mixture into a crucible, and heat it just enough to melt the Sulphur. Part of the Sulphur will be dissipated in vapours, and the rest will burn away. When it is quite consumed, increase the fire so as to make the crucible red-hot. When you perceive no more smell of Sulphur, pour on the Gold a little Borax, previously melted in another crucible with a Fixed Alkali, as calcined Wine- lees, or Nitre fixed with Tartar ; and then raise the fire sufficiently to make the whole flow. After the fusion is completed you will find a button of Gold at the bottom of the crucible under the salts.

Fulminating Gold may also be reduced by pouring on it a sufficient quantity of Fixed Alkali reduced to a liquor, or of oil of Vitriol, evaporating all the moisture, and gradually throwing what remains, mixed up with some pinguious matter, into a crucible kept red-hot in a furnace. The reason why these substances deprive the Gold of its fulminating quality depends on the causes that produce the fulmination.

Gold may also be separated from *Aqua regis*, and precipitated by the means of several metallic substances that have a greater affinity, either with *Aqua regis*, or with one of the two Acids that compose it. Mercury is one of the fittest for this purpose.

pose. On dropping a solution of Mercury in the Nitrous Acid, by little and little, into a solution of Gold, the mixture becomes turbid, and a precipitate is formed. Continue dropping in more of the solution of Mercury till no more precipitate falls, then let the liquor stand to settle, and at the bottom of it you will find a sediment, which is the precipitated Gold: pour off the liquor by inclination, and wash the precipitate with fair water.

Mercury hath a greater affinity with the Marine than with the Nitrous Acid. The affinity which Mercury hath with the Marine Acid is also greater than that of Gold with the Marine Acid; for unless this Acid be associated either with the Nitrous Acid, or at least with a certain proportion of Phlogiston, it will not dissolve Gold. Hence it comes that when a solution of Mercury in the Nitrous Acid is dropped into a solution of Gold in *Aqua regis*, the Mercury unites with the Acid of Sea-salt, which is an ingredient in the *Aqua regis*: but the Marine Acid cannot on this occasion join the Mercury, without deserting the Gold and the Nitrous Acid with which it was united; and then the Gold, which cannot be kept in solution by the Nitrous Acid alone, is forced to quit its solvent and precipitate. The liquor therefore, that now floats over the Gold thus precipitated, must contain Mercury united with the Acid of Sea-salt: and in fact it yields a true Corrosive Sublimate, which is known to be a combination of Mercury with the Marine Acid.

Mercury dissolved in Spirit of Nitre is employed to procure the precipitation we are speaking of because metallic substances, when so comminuted by an Acid, are much fitter for such experiments than when they are in a concrete form.

Gold precipitated in this manner by a metallic substance doth not fulminate.



## P R O C E S S III.

*To dissolve Gold by Liver of Sulphur.*

**M**IX together equal parts of common Brimstone, and a very strong Fixed Alkali ; for instance, Nitre fixed by charcoal. Put them in a crucible, and melt the mixture, stirring it from time to time with a small rod. There is no occasion to make the fire very brisk ; because the Sulphur facilitates the fusion of the Fixed Alkali. Some sulphureous vapours will rise from the crucible ; the two substances will mix intimately together, and form a reddish compound. Then throw into the crucible some little pieces of Gold beat into thin plates, so that the whole do not exceed in weight one third part of the Liver of Sulphur : raise the fire a little. As soon as the Liver of Sulphur is perfectly melted, it will begin to dissolve the Gold with ebullition ; and will even emit some flashes of fire. In the space of a few minutes the Gold will be entirely dissolved, especially if it was cut and flatted into small thin leaves.

## O B S E R V A T I O N S.

The process here delivered is taken from M. Stahl. The design of that ingenious Chymist's enquiry was to discover how Moses could burn the golden calf, which the Israelites had set up and worshipped while he was on the mount ; how he could afterwards reduce that calf to powder, throw it into the water which the people used, and make all who had apostatized drink thereof, as related in the Book of Exodus.

M. Stahl, having first observed that Gold is absolutely inalterable and indestructible by the force of fire alone, be it ever so violent, concludes, that without a miracle Moses could not possibly perform

the above-mentioned operations on the golden calf, any way but by mixing with the Gold some matter qualified to alter and dissolve it. He then takes notice that pure Sulphur does not act upon Gold at all, and that many other substances, which are thought capable of dividing and dissolving it, cannot however do it so completely as is necessary to render that metal susceptible of the effects related. He then gives the method of dissolving it by Liver of Sulphur described in the process.

Liver of Sulphur dissolves likewise all the other metals: but M. Stahl observes that it attenuates Gold more than any other metallic substance, and unites with it much more intimately than with the rest. This appears from what happens, on attempting to dissolve in water any of the mixts resulting from the union of another metal with Liver of Sulphur: for then the metal separates, and appears in the form of a powder or fine calx; whereas, when Gold is united with Liver of Sulphur, the whole compound dissolves in water so perfectly, that the Gold even passes with the Liver of Sulphur through the pores of filtering paper.

If an Acid be poured into a solution of this combination of Gold with Liver of Sulphur, the Acid unites with the Alkali of the *Hepar*, and the Gold falls to the bottom of the liquor along with the Sulphur, which doth not quit it. The Sulphur thus precipitated with the Gold is easily carried off by a slight torrefaction, after which the Gold remains exceedingly comminuted. The Sulphur of this compound may also be destroyed by torrefaction, without the trouble of a previous solution and precipitation, and then also the Gold remains so attenuated as to be miscible with liquors, and floats on them, or swims in them, in such a manner that it may easily be swallowed with them in drinking. From all this M. Stahl concludes there is great reason to believe

believe it was by means of the Liver of Sulphur that Moses divided, and in a manner calcined, the golden calf, so that he could mingle it with water, and make the Israelites drink it.

## P R O C E S S IV.

*To separate Gold from all other metallic Substances by means of Antimony.*

**H**AVING put the Gold you intend to purify into a crucible, set it in a melting furnace, cover it and make the Gold flow. When the metal is in fusion cast upon it, by a little at a time, twice its weight of pure crude Antimony in powder, and after each projection cover the crucible again immediately: this done keep the matter in fusion for a few minutes. When you perceive that the metallic mixture is perfectly melted, and that its surface begins to sparkle, pour it out into a hollow iron cone, previously heated, and smeared on the inside with tallow. Immediately strike with a hammer the floor on which the cone stands; and when all is cold, or at least sufficiently fixed, invert the cone and strike it: the whole metallic mass will fall out, and the under part thereof, which was at the point of the cone, will be a Regulus more or less yellow as the Gold was more or less pure. On striking the metallic mass the Regulus will freely part from the sulphureous crust at top.

Return this Regulus into the crucible, and melt it. Less fire will do now than was required before. Add the same quantity of Antimony, and proceed as at first. Repeat the same operation a third time, if your Gold be very impure.

Then put your regulus into a good crucible, much larger than is necessary to hold it. Set your crucible in a melting furnace, and heat the matter



but just enough to make it flow, with a smooth, brilliant surface. When you find it thus conditioned, point towards it the nose of a long-snouted pair of bellows, and therewith keep gently and constantly blowing. There will arise from the crucible a considerable smoke, which will abate greatly when you cease to blow, and increase as soon as you begin again. You must raise the fire gradually as you approach towards the end of the operation. If the surface of the metal lose its brilliant polish, and seem covered with a hard crust, 'tis a sign the fire is too weak; in which case it must be increased, till the surface recover its shining appearance. At last, when no more smoke rises, and the surface of the Gold looks neat and greenish, cast on it, by little and little, some pulverized Nitre, or a mixture of Nitre and Borax. The matter will swell up. Continue thus adding more Nitre gradually, till no commotion is thereby produced in the crucible; and then let the whole cool. If you find, when the Gold is cold, that it is not tough enough, melt it over again; when it begins to melt cast in the same Salts as before; and repeat this till it be perfectly ductile.

#### OBSERVATIONS.

ANTIMONY is a compound, consisting of a semi-metallic part united with about a fourth part of its weight of common Sulphur. It appears, in the ninth column of the Table of Affinities, that all the metals, Mercury and Gold excepted, have a greater affinity than the reguline part of Antimony with Sulphur. If therefore Gold, adulterated with a mixture of Copper, Silver, or any other metal, be melted with Antimony, those metals will unite with the Sulphur of the Antimony, and separate it from the reguline part, which being thus set free will combine and be blended with the Gold. These

two metallic substances, forming a mass far heavier than the other metals mixed with the sulphur, fall together to the bottom of the crucible in the form of a Regulus, while the others float over them like a sort of scoria or slag: and thus the Gold is freed from all alloy but the reguline part of the Antimony.

As all the other metals have a great affinity with Sulphur, and Gold is the only one that is capable of resisting its action, one would think Sulphur alone might be sufficient to free it from the metals combined with it, and that it would therefore be better to employ pure Sulphur, in this operation, than to make use of Antimony; the reguline part of which remaining united with the Gold requires another long and laborious operation to get rid of it.

Indeed, strictly speaking, Sulphur alone would be sufficient to produce the desired separation: but it is proper to observe that, as Sulphur alone is very combustible, most of it would be consumed in the operation before it could have an opportunity to unite with the metallic substances; whereas when it is combined with the Regulus of Antimony, it is thereby enabled to bear the action of the fire much longer without burning, and consequently is much fitter for the purpose in question. Besides, if we were to make use of pure Sulphur, a great part of the Gold, which is kept in perfect fusion, and its precipitation facilitated, by the Regulus of Antimony, would remain confounded with the sulphureous scoria.

Nevertheless, seeing the metals with which Gold is alloyed cannot be separated from it by Antimony, but that a quantity of Regulus proportioned to the quantity of the metals so separated will unite with the Gold, and that the more Regulus combines with the Gold, the more tedious, chargeable, and laborious will the operation prove, this consideration

ought to have some influence in directing our process. Therefore; if the Gold be very impure, and worse than sixteen carats, we must not mix it with crude Antimony alone, but add two drams of pure Sulphur for every carat the Gold wants of sixteen, and lessen the quantity of Antimony in proportion to that of the real Gold.

It is necessary to keep the crucible close covered, after mixing the Antimony with the Gold, to prevent any coals from falling into it: for, if that should happen, the melted mass would puff up considerably, and might perhaps run over.

The inside of the cone, into which you pour the melted metallic mass, must be greased with tallow, to prevent its sticking thereto, and that it may come easily out. Striking the floor, on which the cone with the melted metal stands, helps the precipitation and descent of the Regulus of Gold and Antimony to the bottom of the cone.

Less fire is requisite to melt this compound Regulus, in order to add fresh Antimony, than was necessary before the Gold was mixed with the reguline part of the Antimony; because this metallic substance, being much more fusible than Gold, promotes its melting. The Antimony is mixed with the Gold by repeated projections, that the separation of the metals may be accomplished with the greater ease and accuracy. Yet the operation might be successfully performed, by putting in all the Antimony at once, and with one melting only.

The metalline mass found at the bottom of the cone after all these operations, is a mixture of Gold with the reguline part of the Antimony. All the rest of the process consists only in separating this reguline part from the Gold. As Gold is the most fixed of all metals, and as the Regulus of Antimony cannot bear the violence of fire without flying off in vapours, nothing more is necessary for this purpose  
but



but to expose the compound, as directed in the process, to a heat strong enough, and long enough continued, to dissipate all the Regulus of Antimony. This semi-metal exhales in the form of a very thick white smoke. It is proper to blow gently into the crucible during the whole operation; because the immediate contact of the fresh air incessantly thrown in promotes and considerably increases the evaporation: and this is a general rule applicable to all evaporations.

The fire must be gradually raised as the Regulus of Antimony is dissipated, and the operation draws toward the end; because the mixed mass of Regulus of Antimony and Gold becomes so much the less fusible as the proportion of the Regulus is lessened. Though the Regulus of Antimony be separated from the Gold in this operation, because the latter is of such a fixed nature that it cannot be volatilized by the degree of fire which dissipates the Regulus; yet, as the Regulus is very volatile, it will undoubtedly carry up some of the Gold along with it, especially if you hurry on the evaporation too fast, by applying too great a degree of fire, by blowing too briskly into the crucible, and still more if you evaporate your mixture in a broad flat vessel instead of a crucible. All these things must therefore be avoided, if you would lose no more Gold than you needs must.

However, unless the evaporation be carried to the utmost, by the means above pointed out, a small portion of the Regulus of Antimony will always remain combined with the Gold, which defends it from the action of the fire. This small portion of Regulus hinders the Gold from being perfectly pure and ductile. In order therefore to consume and scorify it, we cast Nitre into the crucible when we perceive it to emit no more white vapours.

We

We know that Nitre has the property of reducing all metallic substances to a calx, Gold and Silver excepted; because it deflagrates with the phlogiston to which their metalline form is owing: but as this accension of the Nitre occasions a tumid effervescence, care must be taken to throw it in but by little and little at a time; for if too much be projected at once the melted matter will run over.

This operation might be considerably abridged by taking advantage of the property which Nitre possesses of thus consuming the phlogiston of metallic substances; as by means thereof we might destroy all the Regulus of Antimony incorporated with the Gold, without having recourse to a long and tedious evaporation. But then we should at the same time lose a much greater quantity of Gold, by reason of the tumult and ebullition which are inseparable from the detonation of Nitre. On the whole therefore, if Nitre be made use of to purify Gold, great care must be taken to apply but very little of it at a time.

All the Silver that was mixed with the Gold, and indeed a little of the Gold itself, remains confounded with the sulphureous scoria, which floats upon the Golden Regulus after the addition of the Antimony: we shall shew in the Chapter on Silver how these two metals are to be separated from the Sulphur.

## C H A P. II.

## Of SILVER.

## P R O C E S S I.

*To separate Silver from its Ore, by means of Scorification with Lead.*

**B**EAT to powder in an iron mortar the ore from which you mean to separate the Silver, having first roasted it well in order to free it from all the Sulphur and Arsenic that it may contain. Weigh it exactly: then weigh out by itself eight times as much granulated Lead. Put one half of this Lead into a test, and spread it equally thereon: upon this Lead lay your ore, and cover it quite over with the remaining half of the Lead.

Place the test thus loaded under the further end of the Muffle in a cupelling furnace. Light your fire, and increase it by degrees. If you look through one of the apertures in the door of the furnace you will perceive the ore, covered with calcined Lead, swim upon the melted Lead. Presently afterwards it will grow soft, melt, and be thrown towards the sides of the vessel, the surface of the Lead appearing in the midst thereof bright and shining like a luminous disc: the Lead will then begin to boil, and emit fumes. As soon as this happens, the fire must be a little checked, so that the ebullition of the Lead may almost entirely cease, for about a quarter of an hour. After this it must be excited to the degree it was at before, so that the Lead may begin again to boil and smoke. Its shining surface will gradually lessen, and be covered with *scoriae*. Stir the whole with an iron hook, and draw in towards  
the



the middle what you observe towards the sides of the vessel; to the end, that, if any part of the ore should still remain undissolved by the Lead, it may be mixed therewith.

When you perceive that the matter is in perfect fusion, that the greatest part of what sticks to the iron hook, when you dip it in the melted matter, separates from it again, and drops back into the vessel; and that the extremity of this instrument when grown cold, appears varnished over with a thin, smooth, shining crust; you may look on these as marks that the business is done, and the more uniform and evenly the colour of the crust is, the more perfect may you judge the scorification to be.

Matters being brought to this pass, take the test with a pair of tongs from under the muffle, and pour its whole contents into an iron cone, first heated and greased with tallow. This whole operation lasts about three quarters of an hour. When all is cold, the blow of a hammer will part the Regulus from the scoria; and as it is not possible, how perfect soever the scorification be, to avoid leaving a little Lead containing Silver in the scoria, it is proper to pulverise this scoria, and separate therefrom whatever extends under the hammer, in order to add it to the Regulus.

### OBSERVATIONS.

Silver, as well as Gold, is often found quite pure, and under its metalline form, in the bowels of the earth; and in that case it may be separated from the stones or sand, in which it is lodged, by simple washing, or by Amalgamation with Mercury, in the same manner as before directed for Gold. But it also happens frequently that Silver is combined in the ore with other metallic substances and minerals, which will not admit of this process, but force us to employ other methods of separating it from them.

Sulphur

Sulphur and Arsenic are the substances to which Silver and the other metals usually owe their mineral state. These two matters are never very closely united with Silver; but may be pretty easily separated from it by the action of fire, and the addition of Lead. If Arsenic be predominant in a Silver ore, it will unite with the Lead by the help of a pretty moderate heat, and quickly convert a considerable quantity thereof into a penetrating fusible glass, which has the property of scorifying with ease all substances that are capable of scorification.

When Sulphur predominates, the scorification proceeds more slowly, and doth not always succeed; because that mineral combined with Lead lessens its fusibility, and retards its vitrification. In this case part of the Sulphur must be dissipated by roasting: the other part unites with the Lead; and that, being rendered lighter by this union, floats on the rest of the mixture, which chiefly contains the Silver. At last the joint action of the air and of the fire, dissipates the portion of Sulphur that had united with the Lead: the Lead vitrifies and reduces to a scoria whatever is not either Silver or Gold: and thus the Silver being disentangled from the heterogeneous matters with which it was united, one part thereof being dissipated and the other vitrified, combines with the portion of Lead which is not vitrified, and falls through the scoria, which to favour its descent must be in perfect fusion.

The whole process therefore consists of three distinct operations. The first is Roasting, which dissipates some of the volatile substances found united with the Silver: the second is Scorification, or the Vitrification of the fixed matters also united with the Silver, such as sand, stones, metals, &c. and the third is Precipitation, or the separation of the Silver from the scoria. The two first are, as hath been shewn, preparatives for the last, and indeed produce it.

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As every thing we said concerning Gold, when we treated of the process of Amalgamation, is to be applied to Silver, which may be attracted by the same method when it is in its metalline form; in the same manner all we now advance touching the method of extracting Silver by Scorification, when it is depraved with a mixture of heterogeneous matters, is equally applicable to Gold in the same circumstances: and indeed Silver almost always contains more or less Gold naturally.

In the process we directed that the ore should be pulverized before it be exposed to the fire, with a view to enlarge its surface, and by that means facilitate the action of the Lead upon it, as well as the evaporation of its volatile parts.

We recommended the precaution of slackening the fire a little at the beginning of the operation, only to prevent the Lead from being too hastily converted into litharge, lest it should penetrate and corrode the test before it had wholly dissolved the ore: but if we were perfectly certain of the vessel's being so good as to be in no danger of penetration by the Lead, this precaution would be needless.

It is proper to add eight parts of Lead for one of ore; though so much is not always absolutely necessary, especially when the ore is very fusible. The success of this operation depends chiefly on the completeness of the Scorification; and therefore the addition of more Lead than enough is attended with no inconvenience: for, as it always promotes the scorification, it never can do any harm.

If the ore be mixed with such earthy and stony parts as cannot be separated from it by washing, it is the more difficult of fusion, even though the stones should be such as are most disposed to vitrify; because the most fusible earths and stones are always less so than most metallic substances. In that case it will be necessary, for effecting the Scorification,



to mix thoroughly with the pulverized ore an equal Quantity of Glass of Lead, to add twelve times as much granulated Lead, and then to proceed as directed for a fusible ore; exposing the mixture to a degree of fire strong enough, and long enough kept up, to give the scoria all the properties above required as signs of a perfect scorification.

Silver ore is sometimes mixed with pyrites, and the ore of Arsenic, or cobalt, which also make it refractory. As the pyrites contain a large quantity of Sulphur, which is very volatile as well as Arsenic; in this case it is proper to begin with freeing the ore from these two extraneous substances. This is easily done by roasting: only be sure, when you first expose the ore to the heat, to cover the vessel in which you roast it, for some minutes, with an inverted vessel of the same width; because such sorts of ore are very apt to fly when they first feel the heat.

After this uncover it, and leave it exposed to the fire till no more sulphureous or arsenical matters rise. Then mix it with the same quantity of Glass of Lead as we ordered for ores rendered refractory by the admixture of earths and stones, and proceed in the same manner.

It is the more necessary to roast Silver ore infected with Sulphur and Arsenic, because, as Sulphur obstructs the fusion of Lead, it cannot but do hurt, and protract the operation; and Arsenic does mischief, on the other hand, by scorifying a very great quantity of Lead too hastily.

When the Sulphur and Arsenic are dissipated by roasting, the ore must be treated like that which is rendered refractory by stony and earthy matters; for as the pyrites contain much iron, there remains, after the Sulphur is evaporated, a considerable quantity of martial earth, which is difficult to scorify. The pyrites as well as the cobalts, contain more-over an unmetallic earth, which is hard to fuse.

The

The general rule therefore is, when the ore is rendered refractory by any cause whatever, to mix it with Glafs of Lead, and to add a larger quantity of granulated Lead. Yet some ores are so refractory that Lead alone will not do the business, and recourse must be had to some other flux. That which is fittest for the present purpose is the *Black Flux*, composed of one part of Nitre and two parts of Tartar deflagrated together. The Phlogiston contained in this quantity of Tartar is more than sufficient to alkalizate the Nitre. This Flux therefore is nothing more than Nitre alkalized by Tartar, mixed with some of the same Tartar that hath not lost its Phlogiston, and is only reduced to a sort of coal.

The *White Flux* is also very fit to promote fusion; but on this occasion the Black Flux is preferable, because the Phlogiston of the Black Flux prevents the Lead from being too soon converted to litharge, and so gives it time to dissolve the metallic matters. The White Flux, which is the result of equal parts of Tartar and Nitre alkalized together, being no more than an Alkali destitute of Phlogiston, or containing but very little, doth not possess this advantage.

If Silver should be combined in the ore with Iron in its metalline state, which however does not commonly happen, then, in order to separate them, the Iron must be deprived of its Phlogiston, and converted to a *crocus* before the mixed mass be melted with Lead; which may be done by dissolving it in the Vitriolic Acid, and then evaporating the Acid.

We are necessitated to make use of this contrivance, because Iron in its metalline form cannot be dissolved either by Lead or by the Glafs of Lead; but when it is reduced to a calx, litharge unites with it, and scorifies it.

If you have not at hand the utensils necessary for performing the operation we have been describing in  
a test,

a test, and under the muffle; or if you have a mind to work on a greater quantity of ore at a time, you may make use of a crucible for the purpose, and perform the operation in a melting furnace.

In this case the ore must be prepared, as above directed, according to its nature, and mixed with a proper quantity of Lead and Glafs of Lead; the whole put into a good crucible, leaving two thirds thereof empty, and covered with a mixture of Sea-salt and a little Borax, both very dry, to the thickness of a full half inch.

This being done, set the crucible in the midst of a melting furnace, raise the coals quite to the lip of the crucible; light the fire; cover the furnace with its dome; but do not urge the fire more than is necessary to bring the mixture to perfect fusion: leave it thus in fusion for a good quarter of an hour; stir the whole with a bit of strong iron wire; then let it cool; break the crucible, and separate the Regulus from the scoria.

The Salts added on this occasion are fluxes, and their use is to procure a perfect fusion of the scoria.

If the melted matters be left exposed to the fire, either in a test, or in a crucible, longer than is above prescribed, the portion of Lead, that hath united and precipitated with the Silver, will at last vitrify, and at the same time scorify all the alloy with which that metal may be mixed. But as there are no vessels that can long endure the action of litharge, without being pierced like a sieve, some of the silver may escape through the holes or fissures of the vessel, and so be lost. It is better therefore to complete the purification of your Silver by the operation of the Cupel, the description of which follows.



## PROCESS II.

*The refining of Silver by the Cupel.*

**T**AKE a cupel capable of containing one third more matter than you have to put into it: set it under the muffle of a furnace, like that described in our Theoretical Elements, as peculiarly appropriated to this sort of operation. Fill the furnace with charcoal; light it; make the cupel red-hot, and keep it so till all its moisture be evaporated; that is, for about a good quarter of an hour, if the cupel be made wholly of the ashes of burnt bones; and for a whole hour, if there be any washed wood-ash in its composition.

Reduce the Regulus which remained after the preceding operation to thin little plates, flattening them with a small hammer, and separating them carefully from all the adherent scoria. Wrap these in a bit of paper, and with a small pair of tongs put them gently into the cupel. When the paper is consumed, the Regulus will soon melt, and the scoria, which will be gradually produced by the Lead as it turns to litharge, will be driven to the sides of the cupel, and immediately absorbed thereby. At the same time the cupel will assume a yellow, brown, or blackish colour, according to the quantity and nature of the scoria imbibed by it.

When you see the matter in the cupel in a violent ebullition, and emitting much smoke, lower the fire by the methods formerly prescribed. Keep up such a degree of heat only that the smoke which ascends from the matter may not rise very high, and that you may be able to distinguish the colour which the cupel acquires from the scoria.

Increase the fire by degrees, as more and more litharge is formed and absorbed. If the Regulus  
examined

examined by this assay contain no Silver, you will see it turn wholly into scoria, and at last disappear. When it contains Silver, and the quantity of Lead is much diminished, you will perceive little vivid irises, or beautiful rain-bow colours, shooting swiftly along its surface, and crossing each other in many different directions. At last, when all the Lead is destroyed, the thin dark skin, that is continually protruded by the Lead while it is turning into litharge, and which hitherto covered the Silver, suddenly disappears; and, if at this moment the fire happen not to be strong enough to keep the Silver in fusion, the surface of that metal will at once dart out a dazzling splendour: but, if the fire be strong enough to keep the Silver in fusion, though freed from all mixture of Lead, this change of colour, which is called its *fulguration*, will not be so perceptible, and the Silver will appear like a bead of fire.

These phenomena shew that the operation is finished. But the cupel must still be left a minute or two under the muffle; and then drawn slowly out with the iron hook towards the door of the furnace. When the Silver is so cooled as to be but moderately red, you may take the cupel from under the muffle with your little tongs, and in the middle of its cavity you will find an exceeding white bead of Silver, the lower part whereof will be unequal, and full of little pits.

### OBSERVATIONS.

THE Regulus obtained by the former process consists altogether of the Silver contained in the ore, alloyed with the other metals that happened to be mixed therewith in its mineral state, and a good deal of the Lead that was added to precipitate the Silver. The operation of the cupel may be considered as the sequel of that process, being intended only to reduce into a scoria whatever is not Gold or

Silver. Lead being of all metals that which vitrifies the most easily, which most promotes the vitrification of the rest, and the only one which, when vitrified, penetrates the cupel, and carries along with it the other metals which it hath vitrified, is consequently the fittest for that purpose. We shall see in its place that Bismuth hath the same properties with Lead, and may be substituted for it in this operation.

Care must be taken to choose a cupel of a proper capacity. Indeed it should rather be too big than too little: because the operation is no way prejudiced by an excess in its size; whereas, if it be too small, it will be over-dosed with Lead, and at last the litharge, which destroys every thing, will corrode its cavity, and eat holes through the very body of the vessel. Add that the ashes, of which the cupel is made, being once glutted with litharge, absorb it afterwards but slowly, and that the quantity of this vitrified litharge, becoming too great to be contained in the substance of the vessel, exsudes through it, and drops on the floor of the muffle, which it corrodes and renders unequal; and moreover folders to it the vessels set thereon. It may be laid down as a general rule for determining the size of a cupel, that it weigh, at least, half as much as the metallic mass to be refined in it.

It is also of the utmost consequence that the cupel be well dried before the metal be put into it. In order to make sure of this point it must be kept red-hot for a certain time, as is above directed: for tho' to the sight and to the touch it may appear very dry, it nevertheless obstinately retains a small matter of moisture, sufficient to occasion the loss of some of the metal; which, when it comes to melt, will be thereby spirited up, in the form of little globules, to the very roof of the muffle. The cupels, that stand most in need of an intense heat to dry them, are those chiefly



chiefly in whose composition wood-ashes are employed: for whatever care be taken to lixivate those ashes before they are used, they will still retain a little alkaline salt; and that, we know, is very greedy of moisture, will not part entirely with it, but by the means of a violent calcination, and presently re-imbibes it when exposed to the air.

A little Phlogiston also may still be left in the ashes of which the cupels are made; and that is another reason for calcining them before they are used. By this means the remaining Phlogiston is dissipated, which might otherwise combine with the litharge during the operation, reduce it, and occasion such a ferment in the matter as to make some of it run over: to these inconveniencies, which any remainder of moisture or Phlogiston may produce, we must add the cracks and flaws, which are very incident to cupels not perfectly freed from both those matters.

It is of no less importance to the success of this operation, that a due degree of heat be kept up. In the process we have described the marks which shew the heat to be neither too strong nor too weak; when it exceeds in either of these respects may be known by the following signs.

If the fume emitted by the Lead rise like a spout to the roof of the muffle; if the surface of the melted metal be extremely convex, considering the quantity of the mass: if the cupel appear of such a white heat, that the colour communicated thereto by the imbibed scoria cannot be distinguished: all these shew that the heat is too great, and that it ought to be diminished. If, on the contrary, the vapours only hover, as it were, over the surface of the metal; if the melted mass be very flat, considering its quantity; if its ebullition appear but faint; if the *scoriæ*, that appear like little fiery drops of rain, have but a languid motion; if the scoria gather in heaps, and do not penetrate the cupel; if the metal be covered with

it as with a glassy coat; and lastly, if the cupel look dull; these are proofs that the heat is too weak, and ought to be increased.

The design of this operation being to convert the Lead into litharge, and to give it sufficient time and opportunity to scorify and carry off with it whatever is not Gold or Silver; the fire must be kept up to such a degree that the Lead may easily be turned into litharge, and yet that litharge not be absorbed too hastily by the cupel, but that a small quantity thereof may all along remain, like a ring, round the melted metal.

The fire is to be gradually increased as the operation draws nearer to its end: for, as the proportion of the Lead to the Silver is continually lessening, the metallic mass gradually becomes less fusible; while the Silver defends the Lead mixed with it from the action of the fire, and prevents its being easily converted into litharge.

When the operation is finished, the cupel must still be left under the muffle, till it has imbibed all the litharge, to the end that the bead of Silver may be easily taken out: for, without this precaution, it would stick so fast as not to be removed, but by breaking off part of the cupel along with it. Care must also be taken to let this bead of Silver cool gradually, and be perfectly fixed, before you draw it from under the muffle: for if you expose it at once to the cold air, before it be fixed, it will swell, shoot into sprigs, and even dart out several little grains to a considerable distance, which will be lost.

If the bead appear to have a yellowish tinge, 'tis a sign that it contains a great deal of Gold, which must be separated from it by the methods to be hereafter shewn.

It is proper to observe that there is scarce any Lead that does not contain some Silver; too little perhaps to defray the charges necessary to separate it,

yet

yet considerable enough to lead us into an error, by mixing with the Silver obtained from an ore, and increasing its weight. And therefore, when the operations above described are applied to the assaying of an ore, in order to know how much Silver it yields, it is previously necessary to examine the Lead to be used, and to ascertain the quantity of Silver it contains, which must be deducted from the total weight of the bead of Silver obtained by purifying it in this manner.

Silver may be separated from its ore, and at the same time refined, by the single operation of the cupel, without any previous scorification with Lead. In order to do this, you must pound the ore; roast it, to dissipate all its volatile parts; mix it with an equal quantity of litharge, if it be refractory; divide it into five or six parcels, wrapping each in a bit of paper; weigh out eight parts of granulated Lead for one of ore, if it be fusible, and from twelve to sixteen, if it be refractory; put one half of the Lead into a very large cupel under the muffle, add thereto one of the little parcels of ore, when the Lead begins to smoke and boil; immediately slacken the fire a little; continue the same degree of heat till you perceive that the litharge formed round the metal, and on its surface, begins to look bright; then raise the fire; add a fresh parcel of ore; continue proceeding in the same manner till you have put in all the ore; then add the remaining half of the granulated Lead, and conduct the succeeding part of the operation in the same manner as that of cupelling.

In this operation it is necessary that the fire be not too strongly urged, and that it be diminished every time you add a fresh parcel of ore; that so the Lead and the litharge may have time to dissolve, scorify, and carry off into the pores of the cupel, all the adventitious matters with which your Silver may be mixed. Notwithstanding this precaution, when the



ore is refractory, there often gathers in the cupel a great quantity of scoria, together also with some of the ore that could not be dissolved and scorified. It is with a view to remedy this inconvenience that the second moiety of the Lead is added towards the end, which completes the dissolution and scorification of the whole; so that by means thereof no scoria, or very little, is left in the cupel at the end of the operation.

The operation of the cupel is chiefly used to purify Silver from the alloy of Copper; because this metal, being more fixed and harder to calcine than other metallic substances, is the only one that remains united with Silver and Lead, after roasting and scorification with Lead. It requires no less than sixteen parts of Lead to destroy it in the cupel, and separate it from Silver. It melts into one mass with the Lead; and the glass produced by these two metals, deprived of their phlogiston, inclines to a brown or a black colour; by which appearance chiefly we know that our Silver was alloyed with Copper.

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### PROCESS III.

*To purify Silver by Nitre.*

**G**RANULATE the Silver you intend to purify, or reduce it to thin plates; put it into a good crucible; add thereto a fourth part in weight of very dry pulverized Nitre, mixed with half the weight of the Nitre of calcined Wine-lees, and about a sixth part of the same weight of common glass in powder. Cover this crucible with another crucible inverted; which must be of such a size that its mouth may enter a little way into that of the lower one, and have its bottom pierced with a hole of about two lines in diameter. Lute the two crucibles together with clay and Windsor-loam. When  
the

the lute is dry, place the crucibles in a melting furnace. Fill the furnace with Charcoal, taking care however that the fuel do not rise above the upper crucible.

Kindle the fire, and make your vessels of a middling-red heat. When they are so, take up with the tongs a live coal, and hold it over the hole of the upper crucible. If you immediately perceive a vivid splendour round the coal, and at the same time hear a gentle hissing noise, it is a sign that the fire is of a proper strength; and it must be kept up at the same degree till this phenomenon cease.

Then increase the fire to the degree requisite to keep pure Silver in fusion; and immediately after take your vessels out of the furnace. You will find the Silver at the bottom of the lower crucible, covered with a mass of Alkaline scoria of a greenish colour. If the metal be not rendered perfectly pure and ductile by this operation, it must be repeated a second time.

### O B S E R V A T I O N S.

THE purification of Silver by Nitre, as well as the process for refining it on the cupel, is founded on the property which this metal possesses of resisting the force of the strongest fire, and the power of the most active solvents, without losing its phlogiston. The difference between these two operations consists wholly in the substances made use of to procure the scorification of the imperfect metals, or semi-metals, that may be combined with the Silver. In the former this was obtained by Lead, and here it is effected by Nitre. This Salt, as we have shewn, hath the property of calcining and quickly destroying all metallic substances, by consuming their phlogiston, except the perfect metals, Gold and Silver, which alone are able to resist its force. This method may therefore be employed to purify Gold as well as Silver, or indeed both the two mixed together.

In

In this operation the Nitre is gradually alkalinized, as its Acid is consumed with the phlogiston of the metallic substances. The Alkaline Salt and pounded glass are added, with a view to promote the fusion of the metalline calxes, as fast as they are formed, and to fix and retain the Nitre, which, as we shall presently see, is apt to fly off in a certain degree of heat.

The precaution of covering the crucible with another crucible inverted, which hath only a small hole in its bottom, is designed to prevent any of the Silver from being lost in the operation: for when the Nitre comes to be acted on by a certain degree of heat, and especially when it deflagrates with any inflammable matter, part of it flies off, and so rapidly too as to be capable of carrying off with it a good deal of the Silver. The little hole left in the covering crucible is necessary for giving vent to the vapours, which rise during the deflagration of the Nitre, as they would otherwise open themselves a passage by bursting the vessels. After the operation this vent hole is found beset with many little particles of Silver, which would have been lost if the crucible had not been covered.

If you should observe, during the detonation of the Nitre, that a great many vapours issue through the vent-hole with a considerable hissing noise, even without applying the coal, you must take it for a sign that the fire is too brisk, and accordingly check it; else a great deal of the Nitre will be dissipated, and with it much Silver.

You must observe to take the Silver out of the fire as soon as it is in fusion: for if you neglect this, the Nitre being entirely dissipated or alkalinized, the calxes of the metals destroyed by it may possibly recover a little phlogiston, communicated either by the vapours of the charcoal, or by little bits of coal accidentally falling into the crucible; by which  
means



means some portion of those metals being reduced will mix again with the Silver, prevent its having the desired degree of purity and ductility, and oblige you to begin the operation afresh.

## P R O C E S S IV.

*To dissolve Silver in Aqua Fortis, and thereby separate it from every other metalline Substance. The Purification of Aqua Fortis. Silver precipitated by Copper.*

THE Silver you intend to dissolve being beaten into thin plates, put it into a glass cucurbit; pour on it twice its weight of good precipitated *Aqua Fortis*; cover the cucurbit with a piece of paper, and set it on a sand-bath moderately heated. The *Aqua Fortis* will begin to dissolve the Silver as soon as it comes to be a little warm. Red vapours will rise; and from the upper surfaces of the Silver there will seem to issue streams of little bubbles, ascending to the top of the liquor, between which and the Silver they will form, as it were, a number of fine chains: this is a sign that the dissolution proceeds duly, and that the degree of heat is such as it ought to be. If the liquor appear to boil and be agitated, a great many red vapours rising at the same time, it is a sign that the heat is too great, and should be lessened till it be reduced to the proper degree indicated above: having obtained that, keep it equally up till no more bubbles or red vapours appear.

If your Silver be alloyed with Gold, the Gold will be found, when the dissolution is finished, at the bottom of the vessel in the form of a powder. The solution must now be decanted while it is yet warm; on the powder pour half as much fresh *Aqua Fortis* as before, and make it boil; again decant this second *Aqua Fortis*, and repeat the same a third

time; then with fair water wash the remaining powder well: it will be of a brown colour inclining to red. In the observations we shall shew how the Silver is to be separated from the *Aqua Fortis*.

### OBSERVATIONS.

ALL the processes on Silver already delivered, whether for extracting it from its ores, or for refining it, either by the Cupel or by Nitre, are applicable to Gold also. And if Silver be alloyed with Gold before it undergo those several operations, it will still remain alloyed therewith after them, in the same manner, and in the same quantity; because both metals bear them equally. All therefore, that can be expected from those several assays, is the separation of every thing that is neither Silver nor Gold from these two metals. But in order to separate these two from each other, recourse must be had either to the process laid down under the head of Gold, or to that here described, which is the most commodious, the most usual, and known by the names of *Quartation* and the *Parting Assay*.

*Aqua Fortis* is the true Solvent of Silver, and is utterly incapable of dissolving the least atom of Gold. If therefore a mass consisting of Gold and Silver be exposed to the action of *Aqua Fortis*, that Acid will dissolve the Silver contained in the compound, without touching the gold, and the two metals will be separated from each other. This method of parting them is just the reverse of that described before under the head of Gold, which is effected by the means of *Aqua Regis*.

To the success of this separation, by means of *Aqua Fortis*, several conditions are essentially necessary. The first is, that the Gold and Silver be in due proportion to each other; that is, there must be at least twice as much Silver as Gold in the metalline mass, otherwise the *Aqua Fortis* will not be able to dissolve it,

it, for the reason formerly given. If therefore the mass contain too little Silver, it must either be melted down again, and a proper quantity of Silver added; or else, if the Gold be in a sufficient proportion to the Silver, they may be parted by means of *Aqua Regis*.

Secondly, it is necessary that the *Aqua Fortis* employed in this operation be absolutely pure, and free from any taint of the Vitriolic or Marine Acid: for, if it be adulterated with the Vitriolic Acid, the Silver will precipitate as fast as it dissolves, and so the precipitated Silver will again mix with the Gold. If the *Aqua Fortis* contain any of the Marine Acid, the Silver will be precipitated in that case also; and this inconvenience will be attended with another, namely, that the menstruum, being partly an *Aqua Regis*, will dissolve some of the Gold. You must therefore be very sure that your *Aqua Fortis* is pure, before you set about the operation. In order to discover its quality, you must try it by dissolving, in a small portion thereof, as much Silver as it will take up: if the *Aqua Fortis* grow opaque and milky as it dissolves the Silver, 'tis a sign it contains some foreign Acid, from which it must be purified.

In order to effect this, let the portion of *Aqua Fortis* used for the above trial stand to settle: the white milky part will gradually fall to the bottom of the vessel. When it is all fallen, gently decant the clear liquor, and pour a few drops of this decanted solution of Silver into the *Aqua Fortis* which you want to purify. It will instantly become milky. Let the white particles precipitate as before, and then add a few more drops of your solution of Silver. If the *Aqua Fortis* still become milky, let it precipitate again, and repeat this till you find that a drop of your Solution of Silver, let fall into this *Aqua Fortis*, does not make it in the least turbid. Then filter



filter it through brown paper, and you will have an *Aqua Fortis* perfectly fit for the Parting Assay.

The white particles that appear and settle to the bottom, on dissolving Silver in an *Aqua Fortis* adulterated with a mixture of some foreign Acid, are no other than that very Silver, which is no sooner dissolved by the Nitrous Acid than it deserts that solvent to unite with the Vitriolic or Marine Acid, wherewith it has a greater affinity, and falls to the bottom with them. And this happens as long as there remains in the *Aqua Fortis* a single atom of either of those two Acids.

When therefore your *Aqua Fortis* hath dissolved as much Silver as it is capable of taking up, and when all the white particles formed during the dissolution are settled to the bottom, you may be assured that the portion which remains clear and limpid is a solution of Silver in an exceeding pure *Aqua Fortis*. But if the solution of Silver thus depurated be mixed with an *Aqua Fortis* adulterated with the Vitriolic or Marine Acid, a like precipitation will immediately ensue, for the reasons above given, till the very last particle of the heterogeneous Acid contained in the *Aqua Fortis* be precipitated.

*Aqua Fortis* purified by this method contains no extraneous substance whatever, except a small portion of Silver; so that it is very fit for the parting process. But if it be intended for other chymical purposes, it must be rectified in a glass retort with a moderate heat, in order to separate it from the small portion of Silver it contains, which will remain at the bottom of the retort.

The third condition necessary to the success of this operation is, that your *Aqua Fortis* be neither too aqueous, nor too highly concentrated. If too weak, it will not act upon the Silver: and the consequence will be the same if it be too strong. Both these inconveniencies are easily remedied: for in the former case

case part of the superfluous phlegm may be drawn off by distillation; or a sufficient quantity of much stronger *Aqua Fortis* may be mixed with that which is too weak: and in the latter case, very pure rain water, or a weaker *Aqua Fortis*, may be mixed with that which is too strong.

You may satisfy yourself whether or no your *Aqua Fortis* hath the requisite degree of strength, by dissolving therein a thin plate consisting of one part Gold and two or three parts Silver; which plate must be rolled in form of a paper coffin. If, when all the Silver contained in the plate is dissolved, the Gold remains in the form of the coffin, it is a sign that your Solvent has a due degree of strength. If, on the contrary, the Gold be reduced to a powder, it is a proof that your *Aqua Fortis* is too strong, and ought to be weakened.

The Gold remaining after the dissolution of the Silver must be melted in a crucible with Nitre and Borax, as hath already been said under the process for parting Gold and Silver by means of *Aqua Regis*. As to the Silver which remains dissolved in the *Aqua Fortis*, there are several ways to recover it.

The most usual is to precipitate it by the interposition of Copper, which hath a greater affinity than Silver with the Nitrous Acid\*. For this purpose the solution is weakened by adding twice or thrice as much very pure rain water. The cucurbit containing the solution is set on a sand-bath gently heated, and very clean plates of copper put into it. The surfaces of these plates are soon covered with little white scales, which gradually fall to the bottom of the vessel, as they come to be collected in quantities. It is even proper to strike the cucurbit gently now and then, in order to shake the scales of Silver from the copper plates, and so make room for a new crop.

\* See the Table of Affinities, Column IV.

The *Aqua Fortis* parts with the Silver by degrees only, as it dissolves the Copper; and therefore the liquor gradually acquires a bluish green colour as the precipitation advances. This precipitation of the Silver is to be continued as long as any remains dissolved in the *Aqua Fortis*: you may be sure that your liquor contains no more Silver, if the surface of a fresh plate of Copper laid therein remain clean and free from ash-coloured or greyish particles; or if one drop of a solution of Sea-salt let fall into it produce no white or milky cloud.

The precipitation being finished, the liquor is to be gently poured off from the precipitated Silver, which must be rinsed in several waters, and even made to boil therewith, in order to free it wholly from the dissolved Copper. The Silver thus well washed must be thoroughly dried, mixed with a fourth of its weight of a flux compounded of equal part of Nitre and calcined Borax, and then melted in a crucible. On this occasion care must be taken to raise the fire gently and gradually, till the Silver be brought to fusion.

With what accuracy soever the precipitated Silver be washed, in order to free it from the solution of Copper, yet the Silver will always be found alloyed with a small portion of the Copper: but then this Copper is easily destroyed by the Nitre, with which the Silver is afterwards melted; so that the latter metal remains perfectly pure after the operation.

Though the Silver be not previously cupelled, but be alloyed with other metallic substances at the time it is thus dissolved, yet the dissolving, precipitating, and fusing it with Nitre would be sufficient to separate it accurately from them all, and refine it to a degree of purity equal to that obtained by the cupel.

The Copper that remains dissolved by the *Aqua Fortis*, after the precipitation of the Silver, may in like manner be precipitated by Iron, and, as it re-  
tains



tains a small portion of Silver, ought not to be neglected when these operations are performed on considerable quantities.

In the two next processes we shall shew two other methods of separating Silver from *Aqua Fortis*.

## P R O C E S S V.

*To separate Silver from the Nitrous Acid by Distillation. Crystals of Silver. The Infernal Stone.*

**I**NTO a large, low, glass body put the solution of Silver, from which you intend to separate the Silver by distillation. To this body fit a tubulated head provided with its stopple. Set this alembic in a sand-bath, so that the body may be almost covered with sand: apply a receiver, and distil with a moderate heat, so that the drops may succeed each other at the distance of some seconds. If the receiver grow very hot, check the fire. When red vapours begin to appear, pour into the alembic, through the hole in its head, a fresh quantity of your solution of Silver, first made very hot. Continue distilling in this manner, and repeating the addition of fresh liquor, till all your solution be put into the alembic. When you have no more fresh solution to put in, and when, the phlegm being all come over, red vapours begin again to appear, convey into the alembic half a dram or a dram of tallow, and distill to dryness; which being done, increase your fire so as to make the vessel containing the sand-bath red-hot. In the alembic you will find a calx of Silver, which must be melted in a crucible with some soap and calcined wine-lees.

## OBSERVATIONS.

A low cucurbit is recommended for this operation, to the intent that the particles of the Nitrous Acid, which are ponderous, may the more easily be carried up and pass over into the receiver. For the same reason the cucurbit is directed to be almost wholly covered with sand; lest otherwise the acid vapours should be condensed about that part of the cucurbit, which, being out of the sand, would be much cooler than that which is encompassed therewith, and from thence should fall back again to the bottom; by which means the distillation would certainly be retarded, and the vessel probably be broken.

Notwithstanding these precautions the vessels are liable to break in such distillations; especially when they contain a great deal of liquor. With a view therefore to prevent this accident, we ordered that the whole quantity of the solution of Silver to be distilled should not be put at once into the alembic. The little bit of tallow, added towards the end of the operation, is intended to hinder the metal from adhering closely to the vessel, as it would otherwise do, when all the moisture is dissipated.

The Soap and Fixed Alkali mixed with the Silver to flux it, after its separation from the *Aqua Fortis* in this way, serve to absorb such of the most fixed particles of the Acid as may still remain united with the metal.

If the distillation be stopped when part of the phlegm is drawn off, and the liquor be then suffered to cool, many crystals will shoot therein, which are a Neutral Salt constituted of the Nitrous Acid and Silver. If the distillation be carried further, and stopped when near its conclusion, the liquor being

then suffered to cool, will wholly coagulate into a blackish mass called the *Infernal Stone*.

This way of separating Silver from its solvent is attended with the advantage of saving all the *Aqua Fortis*, which is excellent, and fit to be employed in other operations.

## P R O C E S S VI.

*To separate Silver from the Nitrous Acid by Precipitation. Luna Cornea. Luna Cornea reduced.*

**I**N TO your solution of Silver pour about a fourth part in weight of Spirit of Salt, solution of Sea-salt, or solution of Sal Ammoniac. The liquor will instantly become turbid and milky. Add twice or thrice its weight of fair water, and let it stand some hours to settle. It will deposite a white powder. Decant the clear liquor, and on the precipitate pour fresh *Aqua Fortis*, or Spirit of Salt, and warm the whole on a sand-bath with a gentle heat for some time. Pour off this second liquor, and boil your precipitate in pure water, shifting it several times, till the precipitate and the water be both quite insipid. Filter the whole, and dry the precipitate which will be a *Luna Cornea*, and must be reduced in the following manner.

Smear the inside of a good crucible well with soap. Put your *Luna Cornea* into it; cover it with half its weight of Salt of Tartar, thoroughly dried and pulverised; press the whole hard down; pour thereon as much oil, or melted tallow, as the powder is capable of imbibing; set the crucible thus charged, and close covered, in a melting furnace, and, for the first quarter of an hour, make no more than is necessary to make the crucible moderately red: after that raise it so as to melt the Sil-



ver and the Salt, throwing into the crucible from time to time little bits of tallow. When it ceases to smoke, let the whole cool ; or pour it into a hollow iron cone, warmed and tallowed.

### O B S E R V A T I O N S.

THE process here delivered furnishes us with the means of procuring Silver in a degree of purity which is not to be obtained by any other method of treating it whatever. That which is refined on the cupel always retains a small portion of copper, from which it cannot possibly be separated in that way : but if it be dissolved in *Aqua Fortis*, and precipitated thence in a *Luna Cornea* by the Marine Acid, the precipitate will be an absolutely pure Silver, unalloyed with that small portion of Copper which it retained on the cupel. The reason of this effect is, that the Copper remains as perfectly dissolved in Spirit of Salt and in *Aqua Regia* as in *Aqua Fortis* : so that when the Silver, and the Copper with which it is alloyed, are dissolved together in the Nitrous Acid, if the Acid of Sea-salt be mixed with the solution, part of this latter Acid unites with the Silver, and therewith forms a new compound, which not being soluble in the liquor, falls to the bottom. The other part of the Acid mixing with the Nitrous, forms an *Aqua Regis*, in which the Copper remains dissolved, without separating from it.

Fresh Acid is poured on the precipitated calx of Silver, in order to complete the solution of the small portion of Copper that may have escaped the action of the first solvent. It is indifferent whether the Spirit of Salt or the Spirit of Nitre be employed for this purpose, because they both dissolve Copper alike, and because Silver precipitated by Spirit of Salt is not soluble in either.

After

After this it is necessary to wash the precipitate well with pure water, in order to free it entirely from the particles of *Aqua Fortis* adhering to the Silver; because they may possibly contain something of Copper, which would mix with the Silver on melting, and taint its purity.

If this precipitate of Silver be exposed to the fire, unmixed with any other substance, it melts as soon as it begins to be red; and if the fire be increased, part thereof will be dissipated in vapours, and the rest will make its way through the crucible. But being poured out as soon as melted, it coagulates into a cake of a purplish red colour, semitransparent, ponderous, and in some degree pliable, especially if it be very thin. It bears some resemblance to horn, which hath occasioned it to be called *Luna Cornea*.

As *Luna Cornea* is not soluble in water, recourse must be had to fusion, in order to reduce it, by separating from the Silver those acids which give it the abovementioned properties. Fixed Alkalis and fatty matters are very fit to produce that separation.

We directed that the inside of the crucible, in which the reduction is to be made, should be carefully smeared with soap, and that the *Luna Cornea* should be quite covered with a Fixed Alkali and Fat, to the end that when the heat is strong enough to dissipate it in vapours, or to attenuate it so as to render it capable of penetrating the crucible, it may be forced to pass through matters qualified to absorb its Acid, and reduce it.

*Luna Cornea* may also be reduced by being melted with such metalline substances as have a greater affinity than Silver with the Acids where-with it is impregnated. Of this kind are Tin, Lead, Regulus of Antimony: but the *Luna Cornea* flies so impetuously into conjunction with those

metalline substances, that a vast many vapours arise, and carry off with them part of the Silver: if therefore you chuse to effect the reduction by the interposition of such metalline substances, you must employ a retort instead of a crucible.

But this method is attended with another inconvenience; which is, that some part of those metalline substances may unite with the Silver, and adulterate it; for which reason it is best to keep to the method first proposed.

## PROCESS VII.

*To dissolve Silver, and separate it from Gold, by Cementation.*

**M**IX thoroughly together fine brick-duft four parts, Vitriol calcined to redness one part, and Sea-salt or Nitre one part. Moisten this powder with a little water. With this cement cover the bottom of a crucible half an inch thick; on this first bed lay a thin plate of the mass of Gold and Silver you intend to cement, and which you must previously take care to beat into such thin plates. Cover this plate with a second layer of cement, of the same thickness as the former; on this second bed lay another plate of your metal; cover it in like manner with cement; and so proceed till the crucible be filled to within half an inch of its brim. Fill up the remaining space with cement, and close the crucible with a cover, luted with a paste made of Windsor-loam and water: set your crucible thus charged in a furnace, whose fire-place is deep enough to let it be entirely surrounded with coals, quite up to its mouth. Light some coals in the furnace, taking care not to make the fire very brisk at first; encrease it by degrees, but only so far as  
to



to make the crucible moderately red ; keep up the fire in this degree for eighteen or twenty hours : then let the fire go out ; open the crucible when it is cold, and separate the cement from your plates of Gold. Boil the Gold repeatedly in fair water, till the water come off quite insipid.

## O B S E R V A T I O N S.

It cannot but seem strange that, after having so often declared the Acid of Sea-salt to be incapable of dissolving Silver, we should direct either Nitre or Sea-salt indifferently to be employed in composing a cement, which is to produce an Acid capable of eating out all the Silver mixed with Gold. It is easy to conceive how the Nitrous Acid extricated from its basis by means of the Vitriolic Acid may produce this effect : but if Sea-salt instead of Nitre be made an ingredient in the cement, its Acid, though set at liberty in the same manner by the Vitriolic Acid, must at first sight appear unable to answer the end.

In order to remove this difficulty we must here observe that there are two very essential differences between the Marine Acid collected in a liquor, as it is when distilled in the usual manner, and the same Acid separated from its basis in a crucible, as it is in cementation.

The first of these two differences is, that the Acid being reduced into vapours when it acts on the Silver in cementation, its activity is thereby greatly increased : the second is, that in the crucible it sustains a vastly greater degree of heat than it can ever bear when it is in the form of a liquor. For, after it is once distilled and separated from its basis, it cannot sustain any extraordinary degree of heat without being volatilized and entirely dissipated : whereas while it continues united with its basis it is much more fixed, and cannot be separated but by a

very intense heat. Consequently, if it meet with any body to dissolve, at the very instant of its separation from its basis, while it is actuated by a much fiercer heat than can ever be applied to it on any other occasion, it must operate upon that body with so much the more efficacy: and thus it comes to pass that in cementation it has the power of dissolving Silver, which it would be incapable of touching if it were not so circumstanced.

But herein Gold differs from Silver: for, whatever force the Nitrous or the Marine Acid may exert, when extricated from their bases in the cementing crucible, this metal obstinately refuses to yield to either of those Acids separately, and can never be dissolved by them, unless both be united together.

Our cementation therefore is actually a parting process in the dry way. The Silver is dissolved, and the Gold remains unaltered. Nay, as the action of the Acids is much stronger when they are applied this way, than when they are used for dissolution in the moist way, the Nitrous Acid, which in the common parting process will not dissolve Silver unless its weight be double that of the Gold, is able in cementation to dissolve a very small quantity of Silver diffused through a large quantity of Gold.

It sometimes happens that after the operation the cement proves extremely hard, so that it is very troublesome to separate it entirely from the Gold. In this case it must be softened by moistening it with hot water. This hardness which the cement acquires is occasioned by the fusion of the Salts, which is the effect of too strong a heat. It was in order to prevent this, and that a due degree of heat might be applied, without the danger of melting the salts that we directed the cement to be mixed with a considerable quantity of earthy matter incapable  
of

of fusion, such as brick-dust. A greater inconvenience still will ensue, if the fire be made so strong as to melt the Gold: for then it will partly commix again with the other metalline substances dissolved by the cement, and consequently will not be purified.

The crucible is covered, and its cover luted on, to prevent the acid vapours from being too soon dissipated, and to force them to circulate the longer in the crucible. However, it is necessary that those vapours should find a vent at last, otherwise they would burst the vessel: and for this reason we directed the crucible to be luted only with Windfor-loam, which does not grow very hard by the action of fire, and so is capable of yielding and giving passage to the vapours, when a certain quantity of them is collected in the crucible, and they begin to struggle for an escape on every side.

When the operation is finished, the Silver dissolved by the Acid of the cement is partly distributed through the cement, and partly in the Gold itself, which is impregnated therewith. For this reason the Gold must be washed several times in boiling water, till the water become absolutely insipid: for, if the Gold be melted without this precaution, it will mix again with the Silver: the cement also may be washed in the same manner to recover the Silver it contains.

Though this cementation be, properly speaking, a purification of Gold, yet we have placed it among the processes on Silver, because it is the Silver that is dissolved on this occasion, and because this is a particular way of dissolving that metal. Moreover, most of the processes hitherto delivered, either on Gold or Silver, are equally applicable to both these metals.

If the Gold do not appear quite pure after the cementation, the process must be repeated.

There



There are several ways to know the fineness of Gold, the quantity of Silver with which it is alloyed, and the proportion in which these two metals are mixed in a mass purified by the cupel.

One of the simplest is the trial by the Touch-stone; which indeed is hardly any more than judging by the eye only, from the colour of the compound metal, what proportion of Gold and Silver it contains.

The Touch-stone is a sort of black marble, whose surface ought to be half polished. If the metalline mass which you want to try be rubbed on this stone, it leaves thereon a thin coat of metal, the colour of which may be easily observed. Such as are accustomed to see and handle Gold and Silver can at once judge very nearly from this sample in what proportion the two metals are combined: but, for greater accuracy, those who are in the way of having frequent occasion for this trial are provided with a sufficient number of small bars or needles, of which one is pure Gold, another pure Silver, and all the rest consist of these two metals mixed together in different proportions, varied by carats, or even by fractions of carats, if greater exactness be required.

The fineness of each needle being marked on it, that needle, whose colour seems to come nearest the colour of the metalline streak on the Touch-stone, is rubbed on the stone by the side of that streak. This needle likewise leaves a mark; and if there appear to be no difference between the two metalline streaks, the metalline mass is judged to be of the same fineness as the needle thus compared with it. If the eye discovers a sensible difference, another needle is sought for whose colour may come nearer to that of the metal to be tried. But though a man be ever so well versed in judging thus of the fineness of Gold by the eye only, he can never be perfectly and accurately

curately fure of it by this means alone. If fuch certainty be required, recourfe muft be had to the parting affay; and yet when you have gone through it, there always remains a fmall quantity of the metal, which fhould have been diffolved, and yet efcaped the action of the folver. For example, if you make ufe of *Aqua Regis*, the Silver that remains after the operation ftill contains a little Gold; and, if you make ufe of *Aqua Fortis*, the Gold that remains after the operation ftill contains a little Silver. And therefore if you refolve to carry the feparation of thefe two metals ftill further by folver, it will be neceffary, after you have gone through one parting procefs, to perform a fecond the contrary way. For example, if you begin with *Aqua Fortis*, then, after it has diffolved all the Silver in the metalline mafs that it is capable of taking up, diffolve the remaining Gold in *Aqua Regis*; by which means you will feparate the fmall portion of Silver left in it by the *Aqua Fortis*. The contrary is to be done if you made ufe of *Aqua Regis* firft.

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## C H A P. III.

### Of COPPER.

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#### P R O C E S S I.

*To feparate Copper from its Ore.*

**B**EAT your Copper ore to a fine powder, having firft freed it as accurately as poffible, by washing and roafting, from all ftony, earthy, fulphureous, and arfenical parts. Mix your ore thus pulverized with thrice its weight of the black flux; put the mixture into a crucible; cover it with common falt to the thicknefs of half an inch, and prefs  
the

the whole down with your finger. With all this the crucible must be but half full. Set it in a melting furnace; kindle the fire by degrees, and raise it insensibly till you hear the Sea-salt crackle. When the decrepitation is over, make the crucible moderately red-hot for half a quarter of an hour. Then give a considerable degree of heat, exciting the fire with a pair of good perpetual bellows, so that the crucible may become very red-hot, and be perfectly ignited. Keep the fire up to this degree for about a quarter of an hour; then take out the crucible, and with a hammer strike a few blows on the floor whereon you set it. Break it when cold. If the operation hath been rightly and successfully performed, you will find at the bottom of the vessel a hard Regulus, of a bright yellow colour, and semi-malleable; and over it a scoria of a yellowish brown colour, hard and shining, from which you may separate the Regulus with a hammer.

#### OBSERVATIONS.

COPPER in the ore is often blended with several other metallic substances, and with volatile minerals, such as Sulphur and Arsenic. Copper ores also frequently participate of the nature of the pyrites, containing a martial and an unmetallic earth, both of which are entirely refractory, and hinder the ore from melting. In this case you must add equal parts of a very fusile glass, a little borax, and four parts of the black flux, to facilitate the fusion. The black flux is moreover necessary to furnish the Copper with the Phlogiston it wants, or restore so much thereof as it may lose in melting. For the same reason, when any ore, but that of Gold or Silver, is to be smelted, it is a general rule to add some black flux, or other matter abounding with Phlogiston.

The



The Regulus produced by this operation is not malleable, because it is not pure Copper, but a mixture of Copper with all the other metallic substances that were in the ore; except such as were separated from it by roasting, of which it contains but little.

According to the nature of the metallic matters that remain combined with the Copper after this fusion, the colour of the Regulus is either like that of pure Copper, or a little more whitish: it is also frequently blackish; which has procured it the name of *Black Copper*. In this state, and even in general, it is usual enough to call this Regulus by the name of Black Copper, when alloyed with other metallic substances that render it unmalleable, whatever its colour be.

Hence it appears that there may be several different sorts of Black Copper. Iron, Lead, Tin, Bismuth, and the reguline part of Antimony, are almost always combined with the ores of Copper, in a multitude of different proportions; and all these substances, being reduced by the black flux in the operation, mix and precipitate with the Copper. If the ore contain any Gold or Silver, as is pretty often the case, these two metals also are confounded with the rest in the precipitation, and become part of the Black Copper.

Pyritose, sulphureous, and arsenical Copper ores may be fused, in order to get rid of the grosser heterogeneous parts, without previously roasting them; but in this case no alkaline flux must be mixed with the ore; because the Alkali in combination with the Sulphur would produce a Liver of Sulphur, and so dissolve the metalline part; by which means all would be confounded together, and no Regulus, or very little, be precipitated. On this occasion therefore nothing must be added to promote the fusion, but some tender fusile glass, together with a small quantity of borax.

This

This first fusion may also be performed amidst the coals, by casting the ore upon them in the furnace, without using a crucible; and then an earthen vessel, thoroughly heated, or even made red-hot, must be placed under the grate of the fire-place, to receive the metal as it runs from the ore.

The Regulus obtained by this means is much more impure and brittle than Black Copper, because it contains moreover a large quantity of Sulphur and Arsenic; as these volatile substances have not time to evaporate during the short space requisite to melt the ore, and as they cannot be carried off by the action of the fire after the ore is once melted, whatever time be allowed for that purpose. However, some part thereof is dissipated; and the Iron which is in pyritose ores, having a much greater affinity than Copper, and indeed than any other metallic substance, with Sulphur and Arsenic, absorbs another part thereof, and separates it from the Regulus.

This Regulus, it is plain, still contains all the same parts that were in the ore, but in different proportions; there being more Copper, combined with less Sulphur, Arsenic, and unmetallic earth, which have been either dissipated or turned to slag. Therefore if you would make it like Black Copper, you must pound it, roast it over and over, to free it from its Sulphur and Arsenic, and then melt it with the black flux.

If this Regulus contain much Iron, it will be adviseable to melt it once or twice more, before all the Sulphur and Arsenic are separated from it by roasting; for as the Iron, by uniting with these volatile substances, separates them from the Copper, with which they have not so great an affinity; so also the Sulphur and Arsenic, by uniting with the Iron, help in their turn to separate it from the Copper.

PRO-

## P R O C E S S II.

*To purify Black Copper, and render it malleable.*

**B**REAK into small bits the Black Copper you intend to purify; mix therewith a third part in weight of granulated Lead, and put the whole into a cupel set under the muffle in a cupelling furnace, and previously heated quite red. As soon as the metals are in the cupel raise the fire considerably, making use, if it be needful, of a pair of perpetual bellows, to melt the Copper speedily. When it is thoroughly melted, lower the fire a little, and continue it just high enough to keep the metalline mass in perfect fusion. The melted matter will then boil, and throw up some *scoriæ*, which will be absorbed by the cupel.

When most of the Lead is consumed, raise the fire again till the face of the Copper become bright and shining, thereby shewing that all its alloy is separated. As soon as your Copper comes to this state, cover it with charcoal dust conveyed into the cupel with an iron ladle: then take the cupel out of the furnace and let it cool.

## O B S E R V A T I O N S.

Of all the metals, next to Gold and Silver, Copper bears fusion the longest without losing its phlogiston; and on this property is founded the process here delivered for purifying it.

It is necessary the Copper should melt as soon as it is in the cupel, because its nature is to calcine much more easily and much sooner, when it is only red-hot, than when it is in fusion. For this reason the fire is to be considerably raised, immediately on putting the Copper under the muffle, that it may melt



as soon as possible. Yet too violent a degree of fire must not be applied to it : for when it is exposed to such a degree of heat only as is but just necessary to keep it in fusion, it is then in the most favourable condition for losing as little as may be of its phlogiston ; and if the heat be stronger, a greater quantity thereof will be calcined. As soon therefore as it flows it is proper to weaken the fire, and reduce it to the degree just requisite to keep up the fusion.

The Lead added on this occasion is intended to facilitate and expedite the scorification of the metallic substances combined with the Copper. So that the event is here nearly the same as when Gold or Silver is refined on the cupel. The only difference between this refining of Copper, and that of the perfect metals, is, that the latter, as hath been shewn, absolutely resist the force of fire and the action of Lead, without suffering the least alteration ; whereas a good deal of Copper is calcined and destroyed, when it is purified in this manner on the cupel. Indeed it would be wholly destroyed, if a greater quantity of Lead were added, or if it were left too long in the furnace. It is with a view to save as much of it as possible that we order it to be covered with charcoal-dust as soon as the scorification is finished.

The Lead serves moreover to free the Copper expeditiously from the Iron with which it may be alloyed. Iron and Lead are incapable of contracting any union together : so that as fast as the Lead unites with the Copper, it separates the Iron, and excludes it out of the mixture. For the same reason if Iron were combined in a large proportion with Copper, it would prevent the Lead from entering into the composition. Now, as it is necessary to give the more heat, and to keep the Copper to be incorporated with Lead the longer in fusion, as that Copper is alloyed with a greater proportion of Iron,  
some

some black flux must be added on this occasion, to prevent the Copper and the Lead from being calcined before their association can be effected.

Copper purified in the manner here directed is beautiful and malleable. It is now alloyed with no other metalline substance but Gold or Silver, if there were any in the mixed mass. If you desire to extract this Gold or Silver, recourse must be had to the operation of the cupel. The process here given for purifying Copper is not used in large works, because it would be much too chargeable. In order to purify their Black Copper, and render it malleable, the smelters content themselves with roasting it, and melting it repeatedly, that the metallic substances, which are not so fixed as copper, may be dissipated by sublimation, and the rest scorified by fusion.

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### P R O C E S S III.

*To deprive Copper of its Phlogiston by calcination.*

**P**UT your Copper in filings into a test, and set it under the muffle of a cupelling furnace; light the fire, and keep up such a degree of heat as may make the whole quite red, but not enough to melt the Copper. The surface of the Copper will gradually lose its metalline splendour, and put on the appearance of a reddish earth. From time to time stir the filings with a little rod of copper or iron, and leave your metal exposed to the same degree of fire till it be entirely calcined.

### O B S E R V A T I O N S.

In our observations on the preceding process we took notice that Copper, in fusion, calcines more slowly, and less easily, than when it is exposed to a degree of fire barely sufficient to keep it red-hot,

without melting it ; and therefore, the design here being to calcine it, we have directed that degree of heat only to be applied.

The cupelling furnace is the fittest for this operation, because the muffle is capable of receiving such a flat vessel as ought to be used on this occasion, and communicating to it a great deal of heat ; while, at the same time, it prevents the falling in of any coals, which, by furnishing the Copper with fresh phlogiston, would greatly prejudice and protract the operation.

As Copper calcines with great difficulty, this operation is extremely tedious : nay, though Copper hath stood thus exposed to the fire for several days and nights, and seems perfectly calcined, yet it frequently happens that, when you try afterwards to melt it, some of it resumes the form of Copper : a proof that all the Copper had not lost its phlogiston. Copper is much more expeditiously deprived of its phlogiston by calcining it in a crucible with Nitre.

The calx of Copper perfectly calcined is with great difficulty brought to fusion : yet, in the focus of a large burning-glass, it melts and turns to a reddish and almost opaque glass.

By the process here delivered, you may likewise calcine all other metalline substances, which do not melt till they be thoroughly red-hot. As to those which melt before they grow red, they are easily enough calcined, even while they are in fusion.



## P R O C E S S I V.

*To resuscitate the Calx of Copper, and reduce it to Copper, by restoring its Phlogiston.*

**M**IX the Calx of Copper with thrice as much of the black flux; put the mixture into a good crucible, so as to fill two thirds thereof, and over it put a layer of Sea-salt a finger thick. Cover the crucible, and set it in a melting furnace; heat it gradually, and keep it moderately red till the decrepitation of the Sea-salt be over. Then raise the fire considerably by means of a good pair of perpetual bellows; satisfy yourself that the matter is in perfect fusion, by dipping into the crucible an iron wire; continue the fire in this degree for half a quarter of an hour. When the crucible is cold, you will find at its bottom a button of very fine Copper, which will easily separate from the saline scoria at top.

## O B S E R V A T I O N S.

WHAT hath been said before on the smelting of Copper ores may be applied to this process, as being the very same. The observations there added should therefore be consulted on this occasion.

## P R O C E S S V.

*To dissolve Copper in the Mineral Acids.*

**O**N a sand-bath, in a very gentle heat, set a matrafs containing some Copper filings; pour on them twice their weight of Oil of Vitriol. That Acid will presently attack the Copper. Vapours will rise, and issue out of the neck of the matrafs. A vast number of bubbles will ascend from the surface

face of the metal to the top of the liquor, and the liquor will acquire a beautiful blue colour. When the Copper is dissolved, put in a little and a little more, till you perceive the Acid no longer acts upon it. Then decant the liquor, and let it stand quiet in a cool place. In a short time great numbers of beautiful blue crystals will shoot in it. These crystals are called *Vitriol of Copper*, or *Blue Vitriol*. They dissolve easily in Water.

## O B S E R V A T I O N S.

THE Vitriolic Acid perfectly dissolves Copper, which is also soluble in all the Acids, and even in many other menstruums.

This Acid may be separated from the Copper which it hath dissolved by distillation only: but the operation requires a fire of the utmost violence. The Copper remaining after it must be fused with the black flux, to make it appear in its natural form; not only because it still retains a portion of the Acid, but also because it hath lost part of its phlogiston by being dissolved therein. The black flux is very well adapted both to absorb the Acid that remains united with the Copper, and to restore the phlogiston which the metal hath lost.

The most usual method of separating Copper from the Vitriolic Acid is by presenting to that Acid a metal with which it hath a greater affinity than with Copper. Iron being so qualified is consequently very fit to bring about this separation. When therefore plates of Iron well cleaned are laid in a solution of Blue Vitriol, the Acid soon begins to act upon them, and by degrees, as it dissolves them, deposits on their surfaces a quantity of Copper in proportion to the quantity of Iron it takes up. The Copper thus precipitated hath the appearance of small leaves or scales, exceeding thin, and of a beautiful copper-colour. Care must be taken

to shake the Iron-plates now and then, to make the scales of Copper fall off, which will otherwise cover them entirely, hinder the Vitriolic Acid from attacking the Iron, and so put a stop to the precipitation of the remaining Copper.

When these scales of Copper cease to settle on the clean Iron-plates, you may be sure all the Copper that was in the liquor is precipitated, and that this liquor, which was a solution of Copper before the precipitation, is a solution of Iron after it. So that here two operations are performed at one and the same time; to wit, the precipitation of the Copper, and the dissolution of the Iron.

The Copper thus precipitated requires only to be separated from the liquor by filtration, and melted with a little black flux, to become very fine malleable Copper.

The Copper may also be precipitated out of a solution of Blue Vitriol by the interposition of a Fixed Alkali. This precipitate is of a greenish blue colour, and requires a much greater quantity of the black flux to reduce it.

Copper dissolves in the Nitrous Acid, in the Marine Acid, and in *Aqua Regis*; from all of which it may be separated by the same methods as are here ordered with regard to the Vitriolic Acid.



## C H A P. IV.

## Of I R O N.

## P R O C E S S I.

*To separate Iron from its Ore.*

**P**OUND into a coarse powder the martial stones or earths out of which you design to extract the Iron: roast this powder in a test under the muffle for some minutes, and let your fire be brisk. Then let it cool, beat it very fine, and roast it a second time, keeping it under the muffle till it emit no more smell.

Then mix with this powder a flux composed of three parts of Nitre fixed with Tartar, one part of fusile glass, and half a part of Borax and charcoal-dust. The dose of this reducing flux must be thrice the weight of the ore.

Put this mixture into a good crucible; cover it with about half a finger thick of Sea-salt; over the crucible put its cover, and lute it on with Windsor-loam made into a paste with water. Having thus prepared your crucible, set it in a melting furnace, which you must fill up with charcoal. Light the fire, and let it kindle by gentle degrees, till the crucible become red-hot. When the decrepitation of the Sea-salt is over, raise your fire to the highest by the blast of a pair of perpetual bellows, or rather several. Keep up this intense degree of heat for three quarters of an hour, or an whole hour, taking care that during all this time the furnace be kept

kept constantly filling up with fresh coals as the former consume. Then take your crucible out of the furnace; strike the pavement on which you set it several times with a hammer, and let it stand to cool: break it, and you will find therein a Regulus of Iron covered with slag.

## O B S E R V A T I O N S.

IRON ore, like all others, requires roasting, to separate from it, as much as possible, the volatile minerals, Sulphur and Arsenic, which being mixed with the Iron would render it unmalleable. Indeed it is so much the more necessary to roast these ores, as Iron is, of all metallic substances, that which has the greatest affinity with those volatile minerals; on which account no metallic substance whatever is capable of separating it from them by fusion and precipitation.

Fixed Alkalis, it is true, have a greater affinity than Iron with Sulphur; but then the composition which a Fixed Alkali forms with Sulphur is capable of dissolving all metals. Consequently, if you do not dissipate the Sulphur by roasting, but attempt to separate it from the Iron by melting the ore with a Fixed Alkali, the Liver of Sulphur formed in the operation will dissolve the martial part; so that after the fusion you will find little or no Regulus.

All Iron ores in general are refractory, and less fusible than any other; for which reason a much greater proportion of flux, and a much more violent degree of fire, is required to smelt them. One principal cause why these ores are so refractory is the property which Iron itself has of being extremely difficult to fuse, and of resisting the action of the fire so much the more as it is purer, and further removed from its mineral state. Among all the metallic substances it is the only one that is less fusible when combined with that portion of

phlogiston which gives it the metalline form, than when it is deprived thereof, and in the form of a calx.

In smelting-houses Iron ore is fused amidst charcoal, the phlogiston of which combines with the martial earth, and gives it the metalline form. The Iron thus melted runs down to the bottom of the furnace, from whence it is let out into large moulds, in which it takes the shape of oblong blocks, called *Pigs* of Iron. This Iron is still very impure, and quite unmalleable. Its want of ductility after the first melting arises partly from hence, that, notwithstanding the previous roasting which the ore underwent, there still remains, after this first fusion, a considerable quantity of Sulphur or Arsenic combined with the metal.

A certain quantity of quick-lime, or of stones that will burn to lime, is frequently mixed with Iron ore on putting it into the smelting furnace. The lime being an absorbent earth very apt to unite with Sulphur and Arsenic, is of use to separate those minerals from the Iron.

It is also of use to mix some such matters with the ore, when the stones or earths which naturally accompany it are very fusible; for, as the Iron is of difficult fusion, it may happen that the earthy matters mixed with the Iron shall melt as easily as the metal, or perhaps more easily. In such a case there is no separation of the earthy from the metalline part, both of which melt and precipitate together promiscuously: now quick-lime, being extremely refractory, serves on this occasion to check the melting of those matters which are too fusible.

Yet quick-lime, notwithstanding its refractory quality, may sometimes be of use as a flux for Iron. This is the case when the ore happens to be combined with substances which, being united with lime, render it fusible: such are all arsenical matters, and even  
some



some earthy matters, which being combined with quick-lime make a fusible compound.

When the ore of an Iron Mine is found difficult to reduce, it is usually neglected even though it be rich; because Iron being very common, people chuse to work those mines only whose ores are smelted with the most ease, and require the least consumption of wood.

Yet refractory ores are not to be altogether rejected, when another Iron ore of a different quality is found near them. For it often happens that two several Iron ores, which being worked separately are very difficult to manage, and yield at last but bad metal, become very tractable, and yield excellent Iron, when smelted together: and accordingly such mixtures are often made at Iron-works.

The Iron obtained from ores by the first fusion may be divided into two sorts. The one, when cold, resists the hammer, doth not easily break, and is in some measure extensible on the anvil; but if struck with a hammer when red hot flies into many pieces: this sort of Iron hath always a mixture of Sulphur in it. The other sort on the contrary, is brittle when cold, but somewhat ductile when red-hot. This Iron is not sulphurated, is naturally of a good quality, and its brittleness arises from its metalline parts not being sufficiently compacted together.

Iron abounds so much, and is so universally diffused through the earth, that it is difficult to find a body in which there is none at all: and this hath led several Chymists, even men of great fame, into the error of thinking that they had transmuted into Iron several sorts of earths in which they suspected no Iron, by combining them with an inflammable matter; whereas, in fact, all they did was to give them metalline form to a true martial earth which happened to be mixed with other earths.

P R O-

## PROCESS II.

*To render Pig-iron and brittle Iron malleable.*

**I**N T O an earthen vessel widening upwards put some charcoal-dust, and thereon lay the Pig-iron which you propose to render ductile; cover it all over with a quantity of charcoal; excite the fire violently with a pair, or more, of perpetual bellows till the Iron melt. If it do not readily flow and form a great deal of slag on its surface, add some flux, such as a very fusible sand.

When the matter is in fusion keep stirring it from time to time, that all the parts thereof may be equally acted on by the air and the fire. On the surface of the melted Iron *scoriæ* will be formed, which must be taken off as they appear. At the same time you will see a great many sparkles darted up from the surface of the metal, which will form a sort of fiery shower. By degrees, as the Iron grows purer, the number of these sparkles diminishes, though they never vanish entirely. When but few sparkles appear, remove the coals which cover the Iron, and let the slag run out of the vessel; whereupon the metal will grow solid in a moment. Take it out while it is still red-hot, and give it a few strokes with a hammer, to try if it be ductile. If it be not yet malleable, repeat the operation a second time, in the same manner as before. Lastly, when it is thus sufficiently purified by the fire, work it for a long time on the anvil, extending it different ways, and making it red-hot as often as there is occasion. Iron thus brought to the necessary degree of ductility, so as to yield to the hammer, and suffer itself to be extended every way, either hot or cold, without breaking to bits, or even cracking in the least, is very good and very pure.

pure. If it cannot be brought to this degree by the method here prescribed, it is a proof that the ore from which this Iron was extracted ought to be mixed with other ores; but it frequently requires a great number of trials to obtain an exact knowledge of the quality and proportion of those other ores with which it is to be mixed.

### OBSERVATIONS.

THE brittleness and shortness of Pig-iron arises from the heterogeneous parts which it contains, and which could not be separated from it by the first fusion. These extraneous matters are usually Sulphur, Arsenic, and unmetallic earth, and also a ferruginous earth; but such as could not be combined with the phlogiston as it ought to be, in order to have the properties of a metal, and must therefore be considered as heterogeneous, with respect to the other well-conditioned martial particles.

The Pig-iron, by undergoing repeated fusions, is freed from these heterogeneous matters; those which are volatile, such as Sulphur and Arsenic, being dissipated, and the unmetallic matters being scorified. As to the ferruginous earth, which did not at first acquire the metalline form, it becomes true Iron at last; because, among the coals with which it is encompassed, it meets with a sufficient quantity of phlogiston to reduce it to metal. Charcoal is also necessary on this occasion, that it may continually furnish phlogiston to the Iron, which would otherways be converted into a calx.

Hammering the red-hot Iron, after each fusion, serves to force out from amongst the martial parts such earthy matters as may happen to remain there, and so to bring into closer contact the metalline parts which were separated before by the interposition of those heterogeneous matters.



## PROCESS III.

*To convert Iron into Steel.*

**T**AKE small bars of the best Iron; that is, of such as is malleable, both hot and cold; set them on their ends in a cylindrical earthen vessel, whose depth is equal to the length of the bars, and in such a manner that they may be an inch distant from each other, and from the sides of the crucible. Fill the vessel with a cement compounded of two parts of charcoal, one part of bones burnt in a close vessel till they become very black, and one half part of the ashes of green wood; having first pulverised and thoroughly mixed the whole together. Take care to lift up the Iron bars a little, to the end that the cement may cover the bottom of the vessel, and so that there be about the depth of half an inch thereof under every bar: cover the crucible and lute on the cover.

Set the crucible thus prepared in a furnace, so contrived that the crucible may be surrounded with coals from top to bottom: for eight or ten hours keep up such a degree of fire that the vessel may be moderately red; after this take it out of the furnace; plunge your little Iron bars into cold water, and you will find them converted into Steel.

## OBSERVATIONS.

The principal difference between Iron and Steel consists in this, that the latter is combined with a greater quantity of phlogiston than the former.

It appears by this experiment that, to make Iron unite with an inflammable matter, it is not necessary

cessary it should be in fusion; it is sufficient that it be so red-hot as to be opened and softened by the fire.

Every kind of charcoal is fit to be an ingredient in the composition of the cement employed to make Steel, provided it contain no vitriolic Acid. However, it hath been observed that animal coals produce a speedier effect than others: for which reason it is proper to mix something of that kind with charcoal-dust, as above directed.

The following signs shew that the operation hath succeeded, and that the Iron is changed into good Steel.

This metal being quenched in cold water, as proposed above, acquires such an extraordinary degree of hardness, that it will by no means yield to any impression of the file or hammer, and will sooner break in pieces than stretch upon the anvil. And here it is proper to observe, that the hardness of Steel varies with the manner in which it is quenched. The general rule is, that the hotter the Steel is when quenched, and the colder the water is in which you quench it, the harder it becomes. It may be deprived of the temper thus acquired, by making it red-hot, and letting it cool slowly; for it is thereby softened, rendered malleable, and the file will bite upon it. For this reason the artificers who work in Steel begin with untempering it, that they may with more ease shape it into the tool they intend to make. They afterwards new-temper the tool when finished, and by this second temper the Steel recovers the same degree of hardness it had acquired by the first temper.

The colour of Steel is not so white as that of Iron, but darker, and the grains, facets, or fibres, which appear on breaking it, are finer than those observed in Iron.

If the bars of Iron thus cemented in order to convert them into Steel be too thick, or not kept long enough in cementation, they will not be turned into Steel throughout their whole thickness: their surfaces only will be Steel to a certain depth, and the center will be mere iron; because the Phlogiston will not have thoroughly penetrated them. On breaking a bar of this sort, the difference in colour and grain between the Steel and the Iron is very visible.

It is easy to deprive Steel of the superabundant quantity of Phlogiston which constitutes it Steel, and thereby reduce it to Iron. For this purpose it need only be kept red-hot some time, observing that no matter approach it all the while that is capable of refunding to it the Phlogiston which the fire carries off. The same end is still sooner obtained by cementing it with meagre hungry matters, capable of absorbing the Phlogiston; such as bones calcined to whiteness, and cretaceous earths.

Steel may also be made by fusion; or Pig-iron may be converted into Steel. For this purpose the same method must be employed as was above directed for reducing Pig-iron into malleable Iron; with this difference, that, as Steel requires more Phlogiston than is necessary to Iron, all the means must be made use of that are capable of introducing into the Iron a great deal of Phlogiston; such as melting but a small quantity of Iron at a time, and keeping it constantly encompassed with abundance of charcoal; re-iterating the fusions; taking care that the blast of the bellows directed along the surface of the metal do not remove the coals that cover it, &c. And here it must be observed, that there are some sorts of Pig-iron which it is very difficult to convert into Steel by this method, and that there are others which succeed very readily, and with scarce any trouble at all. The ores which yield the last mentioned



tioned sort of Pig-iron are called *Steel Ores*. Steel made by this means must be tempered in the same manner as that made by cementation \*.

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## P R O C E S S IV.

*The Calcination of Iron. Sundry Saffrons of Mars.*

**T**AKE filings of Iron, in what quantity you please; put them into a broad unglazed earthen vessel; set it under the muffle of a cupelling furnace; make it red hot; stir the filings frequently; and keep up the same degree of fire till the Iron be wholly turned into a red powder.

## O B S E R V A T I O N S.

IRON easily loses its phlogiston by the action of fire. The calx that remains after its calcination is exceeding red; which makes this be thought the natural colour of the earth of that metal. It hath accordingly been observed that all the earths and stones, which either are naturally red, or acquire that colour by calcination, are ferruginous.

The yellowish red colour which every calx of Iron hath, in whatever manner it be prepared, hath procured the name of *Crocus* or *Saffron* to every preparation of this kind. That made in the manner above directed is called in Medicine *Crocus Martis astringens*.

The rust produced on the surface of Iron is a sort of calx of Iron made by the way of dissolution.

\* Mr. Réaumur hath obliged the publick with a treatise on the means of converting Iron into Steel, in which he hath exhausted the subject. Such as desire the amplest and most useful instructions, on that part of metallurgy, would do well to consult his Work.

The moisture of the air acts upon the metal, dissolves it, and robs it of some of its Phlogiston. This rust is called in Medicine *Crocus Martis Aperiens*; because it is thought that the saline parts, by means whereof the humidity dissolves the Iron, remain united with the metal after its dissolution, and give it an aperitive virtue. The Apothecaries prepare this sort of Saffron of Mars by exposing Iron filings to the dew, till they be turned entirely to rust; which is then called *Saffron of Mars by dew*.

Another Saffron of Mars is also prepared in a much shorter manner, by mixing filings of Iron with pulverized Sulphur, and moistening the mixture, which after some time ferments and grows hot. It is then set on the fire; the Sulphur burns away, and the mass is kept stirring till it become a red matter. This Saffron is nothing but Iron dissolved by the Acid of Sulphur, which is known to be of the same nature with that of Vitriol; and consequently this Saffron of Mars is no way different from Vitriol calcined to redness.

## P R O C E S S   V.

*Iron dissolved by the mineral Acids.*

**P**UT any mineral Acid whatever into a matrafs with some water; set the matrafs on a sand-bath gently heated; drop into the vessel some filings of Iron: the phenomena which usually accompany metalline dissolutions will immediately appear. Add more filings, till you observe the Acid hath lost all sensible action upon them: then remove your matrafs from the sand-bath; you will find in it a solution of Iron.

O B S E R-

## OBSERVATIONS.

IRON is very easily dissolved by all the Acids. If you make use of the Vitriolic Acid, care must be taken to weaken it with water, in case it be concentrated; because the dissolution will succeed the better. The vapours that rise on this occasion are inflammable; and if a lighted paper be held to the mouth of the matrafs, especially after keeping it topt for some time and shaking the whole gently, the sulphureous vapours take fire with such rapidity as to produce a considerable explosion; which is sometimes strong enough to burst the vessel into a thousand pieces. This solution hath a green colour, and is in fact a fluid Green Vitriol, which wants nothing but rest to make it shoot into crystals.

If you make use of the Nitrous Acid, you must cease adding more filings when the liquor, after standing still some moments, becomes turbid; for, when this Acid is impregnated with iron to a certain degree, it lets fall some of that which it had dissolved, and becomes capable of taking up fresh filings. Thus by constantly adding new supplies of iron, this Acid may be made to dissolve a much greater quantity thereof than is necessary to saturate entirely. This solution is of a russet colour, and doth not crystallize.

If the weather be not extremely cold, and the Acids have a proper degree of strength, the sand-bath is unnecessary, as the dissolution will succeed very well without it.

Iron dissolved by Acids may be separated therefrom, like all other metallic substances in the same circumstances, either by the action of fire, which carries off the Acid and leaves the Martial earth, or by the interposition of substances which have a greater affinity than metallic substances have with Acids; that is, by Absorbent Earths and Alkaline Salts. By



whatever means you separate Iron from an Acid solvent, it constantly appears, after the separation, in the form of a yellowish red powder; because it is then deprived of most of the phlogiston to which it owed its metalline form: whence it is reasonable to think that this is the proper colour of Martial Earth.

All these precipitates of Iron are true Saffrons of Mars, which, as well as those prepared by calcination, are so much the further removed from the nature of a metal, the more they are deprived of their phlogiston. Thence it comes that they are more or less soluble by Acids, and more or less attracted by the magnet: as no ferruginous earth, perfectly deprived of all inflammable matter, is at all attracted by the magnet, or soluble by Acids.

## CHAP. V.

### *Of TIN.*

#### PROCESS I.

*To extract Tin from its Ore.*

**B**REAK your Tin ore into a coarse powder, and by washing carefully separate from it all the heterogeneous matters, and ores of a different kind, that may be mixed therewith. Then dry it, and roast it in a strong degree of fire, till no more Arsenical vapour rise from it. When the ore is roasted, reduce it to a fine powder, and mix it thoroughly with twice its weight of the black flux well dried, a fourth part of its weight of clean iron filings, together with as much borax and pitch: put the mixture into a crucible; over all put Sea-salt to the  
thick-

thickness of four fingers, and cover the crucible close.

Set the crucible thus prepared in a melting furnace: apply at first a moderate and slow degree of fire, till the flame of the pitch, which will escape through the joint of the cover, disappear entirely. Then suddenly raise your fire, and urge it with rapidity to the degree necessary for melting the whole mixture. As soon as the whole is in fusion take the crucible out of the furnace, and separate the Regulus from the scoria.

### OBSERVATIONS.

ALL Tin ores contain a considerable quantity of Arsenic, and no Sulphur at all, or at most very little. Hence it comes that, though Tin be the lightest of all metals, its ore is nevertheless much heavier than any other; Arsenic being much heavier than Sulphur, of which the ores of every other kind always contain a pretty large proportion. This ore is moreover very hard, and is not brought to a fine powder with so much ease as the rest.

These properties of Tin ore furnish us with the means of separating it easily by lotion, not only from earthy and stony parts, but even from the other ores which may be mixed with it. And this is of the greater advantage on two accounts, viz. because Tin cannot endure, without the destruction of a great part thereof, the degree of fire necessary to scorify the refractory matter which accompany its ore; and again because this metal unites so easily with Iron and Copper, the ores of which are pretty commonly blended with Tin ore, that, after the reduction, it would be found adulterated with a mixture of these two metals, if they were not separated from it before the fusion.

But sometimes the Iron ore confounded with that of Tin is very heavy, and is not easily pulverized;

whence it comes to pass that it cannot be separated therefrom by washing only. In that case the magnet must be employed to separate it, after the ore hath been roasted.

Roasting is moreover necessary for Tin ore, in order to dissipate the Arsenic which volatilizes, calcines, or destroys one part of the Tin, and reduces the rest to a short brittle substance, like a Semi-metal. The ore is known to be sufficiently roasted when no more fumes rise from it; when it has lost the smell of garlic; and when it does not whiten a clean plate of Iron held over it.

Tin being one of those metals which are most easily calcined, it is necessary in reducing its ore to employ such matters as may furnish it with phlogiston. In order to defend it from the contact of the air, which always accelerates the calcination of metallic substances, the mixture is to be covered with Sea-salt; and the addition of pitch helps to increase the quantity of phlogiston.

## PROCESS II.

### *The Calcination of Tin.*

**I**NTO an unglazed earthen dish put the quantity of Tin you intend to calcine; melt it, and keep stirring it from time to time. Its surface will be covered with a greyish white powder: continue the calcination till all your Tin be converted into such a powder, which is the *Calx of Tin*.

## OBSERVATIONS.

THOUGH the calcination of metalline substances is promoted by exposing them, in powder or in filings, to the action of fire, and by ordering it so that they may not melt, because they present a much smaller surface when melted than when unmelted; yet



yet we have not directed this precaution to be used in calcining Tin. The reason is, this metal is so fusible that it cannot endure the degree of fire requisite to destroy the phlogiston without melting, and of course, though Tin calcines easily, the operation is nevertheless tedious, because the melted metal presents but a small surface to be acted on by the fire and the air. This inconvenience may be partly remedied, and the operation greatly expedited, by dividing the quantity of Tin to be calcined into several small parcels, and exposing them to the fire in separate vessels, so that they may not re-unite when melted, and form one single mass.

Leaf Tin cast on Nitre in actual fusion causes it to deffagrate and fulminate; and from this mixture there rises a white vapour, which is converted into flowers when it meets with an obstacle to impede its flying off entirely.

Mr. Geoffroy, who went through a course of experiments on Tin, an account whereof may be seen in the Memoirs of the Academy of Sciences, found that from the colour of the calx of that metal a judgment may be formed of its degree of purity, and nearly of the quantity and quality of the metallic substances with which it is alloyed. The experiments tried on this subject by that eminent Chymist are very curious.

He performed the calcination in a crucible, which he heated to a cherry-red, and kept up the same degree of fire from the beginning to the end of the operation. The calx which formed upon his metal, in that degree of heat, appeared like small white scales, a little reddish on the under side. He pushed it to one side as it formed, to the end that it might not cover the surface of the metal, which, like all others, requires the contact of the air to turn it into a calx.

“ While he was making these calcinations, he had  
“ an opportunity of observing a curious fact, of  
“ which nobody before him had ever taken notice;  
“ probably because nobody had ever calcined Tin  
“ by the same method. The fact is, that during  
“ the calcination of the Tin, whether you break the  
“ pellicle which forms on the surface of the metal  
“ while in red-hot fusion, or whether you let it re-  
“ main without touching it, you perceive in several  
“ places a small swell of a certain matter, which bursts  
“ and makes its way through the pellicle. This  
“ matter puffs up, grows red, at the same instant  
“ takes fire, and darts out a small whitish flame,  
“ as vivid and as brilliant as that of Zinc, when  
“ urged by a fire strong enough to sublime it into  
“ flowers. The vividness of this flame may be fur-  
“ ther compared to that of several small grains of  
“ phosphorus of urine fired and gently dropped on  
“ boiling water. From this bright flame a white  
“ vapour exhales; after which the swelled mass  
“ partly crumbles down, and turns to a light white  
“ powder, sometimes spotted with red, according  
“ to the force of the fire. After this momentary  
“ ignition, there arise stronger, more numerous, or  
“ more frequent heavings of matter, out of which  
“ issues a good deal of white fume, that may be in-  
“ tercepted by a cover of tin-plate or copper fitted  
“ to the crucible, and appears to be the flowers of  
“ Tin, which in some measure corrode these metals.  
“ Hence Mr. Geoffroy conjectures, with a great deal  
“ of probability, that their sublimation is promoted  
“ by a portion of Arsenic. When the crust formed  
“ by this calx comes to be too thick or in too great  
“ a quantity, to be pushed on one side, so as to leave  
“ part of the metal uncovered, Mr. Geoffroy puts  
“ out the fire, because no more calx would be form-  
“ ed; the communication of the external air with  
“ the Tin in fusion being absolutely necessary there-  
“ to,

“ to, as hath been already said. In this operation  
 “ it is to be observed that, if the fire be too slow,  
 “ neither the inflammation of the sulphureous par-  
 “ ticles, nor the white fumes that rise, will be so  
 “ distinctly perceived, as when the fire is of the  
 “ degree requisite to keep the crucible just of a  
 “ cherry-red heat.

“ Mr. Geoffroy having taken off this first calx  
 “ began the calcination anew. In this second heat  
 “ the buddings or heavings were more considerable;  
 “ and shot up in the form of cauli-flowers; but were  
 “ still composed of little scales. The thoroughly cal-  
 “ cined portion of this vegetation was likewise white  
 “ and red; and the inferiour surfaces of some little  
 “ bits thereof were wholly red. When these calci-  
 “ nations are continued, sulphureous vapours rise  
 “ seemingly of another kind than those which ap-  
 “ peared in the beginning; for all the calx made  
 “ by the first heat was perfectly white; whereas in  
 “ the second it begins to be spotted here and there  
 “ with a tinge of black. Mr. Geoffroy was obliged  
 “ to go through a course of twelve several calcina-  
 “ tions before he could convert two ounces of Tin  
 “ into a calx. He had the opportunity, during  
 “ these several calcinations, to observe that after  
 “ the fourth, and sometimes after the third, the  
 “ red spots of the calx decrease, and the black in-  
 “ crease; that the germinations cease; that the crust  
 “ of the calx remains flat; that in the twelfth fire  
 “ the Tin yields no more of this scaly crust; that  
 “ towards the end the undulations of the fused  
 “ metal appear no longer; and that the small re-  
 “ mainder of calx is mixed with several very minute  
 “ grains of metal, which seem much harder than  
 “ Tin. Mr. Geoffroy could not collect a sufficient  
 “ quantity thereof to cupel them, and satisfy him-  
 “ self whether or no they were Silver.”



Though Tin, and all the imperfect metals in general, seem converted to a calx, and lose the metalline form by one single calcination, and that a slight one; yet they are not wholly deprived of their phlogiston: for if the calx of Tin, for instance, prepared according to the process above delivered, be cast upon Nitre in fusion, it will make that salt deflagrate very perceptibly; a convincing proof that it still contains much inflammable matter. If therefore a calx be required absolutely free from phlogiston, this first calx must be re-calcined by a more violent fire, and the calcination continued till all the phlogiston be dissipated.

“ Mr. Geoffroy being desirous of having his calx  
 “ of Tin very pure and perfectly calcined, exposed  
 “ oncemore to the action of fire the twelve portions  
 “ of calx obtained by his former calcinations. But,  
 “ as it would have been too tedious to re-calcine  
 “ them all separately, he made four parcels of the  
 “ whole, each consisting of three taken according to  
 “ the order in which they were first calcined; and  
 “ gave to each a fire sufficiently strong, and long  
 “ enough continued, to calcine them as thoroughly  
 “ as was possible. After this second calcination he  
 “ found them all of a most beautiful white, except  
 “ the first parcel: as that consisted of the portions  
 “ obtained by the three first heats, in all of which  
 “ there were scales tinged with red, it still retained  
 “ a stain of carnation, though hardly perceptible.  
 “ Agreeably to the general rule, the two ounces of  
 “ Tin gained in weight by being thus calcined; and  
 “ the increase was two drams and fifty-seven grains.  
 “ Mr. Geoffroy observes that no Tin, but what  
 “ is absolutely pure, will yield a perfectly white  
 “ calx. He calcined in this manner several other  
 “ parcels of Tin that were impure and variously al-  
 “ loyed; each of which produced a calx differently  
 “ coloured, according to the nature and quantity of  
 “ its

“ its alloy : whence he justly concludes, that calcination is a very good method of trying the fineness of Tin, or its degree of purity.” The particulars of Mr. Geoffroy’s experiments on this subject, which are very curious, may be seen in the Memoirs of the Academy for 1738.

It is proper to take notice that a man should be very cautious how he exposes himself to the vapours of Tin, because they are dangerous ; this metal being very justly suspected by Chymists of containing something Arsenical.

### PROCESS III.

*The dissolution of Tin by Acids. The Smoking Liquor of Libavius.*

**P**UT into a glass vessel what quantity you please of fine Tin cut into little bits. Pour on it thrice as much *Aqua Regis*, compounded of two parts *Aqua Fortis* weakened with an equal quantity of very pure water, and one part Spirit of Salt. An ebullition will arise, and the Tin will be very rapidly dissolved ; especially if the quantities of metal and *Aqua Regis* be considerable.

### OBSERVATIONS.

Tin is soluble by all the Acids ; but *Aqua Regis* dissolves it best of any. Yet in this dissolution it comes to pass that part of the dissolved Tin precipitates of its own accord to the bottom of the vessel, in the form of a white powder. The solution of Tin is very fit for preparing the purple-coloured precipitate of Gold. For this purpose the solution of Tin must be let fall, drop by drop, into a solution of Gold. Spirit of Nitre dissolves Tin nearly as *Aqua Regis* does ; but it occasions a greater quantity of calx.

If

If two or three parts of Oil of Vitriol be poured on one part of Tin, and if the vessel in which the mixture is made be exposed to such a degree of heat as to evaporate all the moisture, there will remain a tenacious matter sticking to the sides of the vessel. If water be poured on this matter, and it be then exposed a second time to the fire, it will dissolve entirely, excepting a small portion of a glutinous substance, which also may be dissolved in fresh Oil of Vitriol.

The Acid of Sea-salt may be combined with Tin by the following process. Mix perfectly, by trituration, in a marble mortar, an amalgam of two ounces of fine Tin, and two ounces and a half of Quick-silver, with as much Corrosive Sublimate. As soon as the mixture is completed, put it into a glass retort, and distill with the same precautions as we directed to be used in preparing concentrated and smoking Acids. There will first come over into the receiver some drops of a limpid liquor, which will soon be followed by an elastic spirit that will issue out with impetuosity. At last some flowers, and a saline tenacious matter will rise into the neck of the retort. Then stop your distillation, and pour into a glass bottle the liquor you will find in the receiver. This liquor continually exhales a considerable quantity of dense, white fumes, as long as it is allowed to have a free communication with the air.

The product of this distillation is a combination of the Acid of Sea-salt with Tin. As the affinity of Tin with this Acid is greater than that of Mercury, the Acid contained in the Corrosive Sublimate quits the Mercury, wherewith it was united, to join the Tin; which it volatilizes so as to make it rise with itself in a liquid form. We make use of the amalgam of Tin with Quick-silver, because we are thereby enabled to mix the Corrosive Sublimate perfectly there-



therewith, as the success of the operation requires it should be.

In this experiment the Tin is volatilized, and the Acid of Sea-salt, which is exceedingly concentrated, flies off incessantly in the form of white vapours. This compound is known in Chymistry by the name of *the Smoking Liquor of Libavius*; a name derived from its quality, and from its Inventor. Tin dissolved by Acids is easily separated from them by Alkalis. It always precipitates in the form of a white calx.

## C H A P. VI.

### *Of* L E A D.

## P R O C E S S I.

*To extract Lead from its Ore.*

**H**AVING roasted your Lead ore reduce it to a fine powder; mix it with twice its weight of the black flux, and one fourth of its weight of clean iron filings and borax; put the whole into a crucible capable of containing at least thrice as much; over all put Sea-salt four fingers thick; cover the crucible; lute the juncture: dry the whole with a gentle heat, and set it in a melting furnace.

Make the crucible moderately red: you will hear the Sea-salt decrepitate, and after the decrepitation a small hissing in the crucible. Keep up the same degree of fire till that be over.

Then throw in as many coals as are necessary to complete the operation entirely, and raise the fire suddenly, so as to bring the whole mixture into perfect fusion. Keep up this degree of fire for a quarter

ter of an hour, which is time sufficient for the precipitation of the Regulus.

When the operation is finished, which may be known by the quietness of the matter in the crucible, and by a bright vivid flame that will rise from it, take the crucible out of the furnace, and separate the Regulus from the scoria.

### OBSERVATIONS.

ALL Lead ore contains a good deal of Sulphur, which must be first separated from it by roasting: and as this kind of ore is apt to fly when first exposed to the fire, it is proper to keep it covered till it be thoroughly heated. Another precaution to be used, in roasting this ore, is not to give it too great a heat, but to keep the vessel which contains it just moderately red; because it easily turns clammy, which occasions it to stick to the vessel.

The Iron that is added, and mixed with the flux, absorbs the Sulphur which may happen to remain, even after roasting: it helps also to separate from the Lead some portions of semi-metal, especially of Antimony, which are frequently mixed with this ore.

There is no fear lest the Iron mix with the Lead in fusion, and adulterate it: for these two metals are incapable of contracting any union together, when each has its metalline form.

Nor is there any reason to apprehend lest the Iron should, by its refractory quality, obstruct the fusion of the mixture; for though this metal be not fusible when alone, yet, by the union it contracts with the matters it is designed to absorb, it becomes so to such a degree as in some measure to perform, on this occasion, the office of a flux.

The government of the fire is a point of great consequence in this operation. It is necessary to apply but a moderate degree of heat at first: for, when the metallic earth of the Lead, combining with the  
phlogiston,

phlogiston, acquires the metalline form, it swells up in such an extraordinary manner, that there is great danger lest the matter should overflow, and run all out of the containing vessel. With a view therefore to avoid this inconvenience, we direct a very large crucible to be used. This heaving of the Lead, at the instant of its reduction, is attended with a noise like the whistling of wind.

Notwithstanding all the precautions that can be used to prevent the reduction from taking place too hastily, and so occasioning the effusion of the matter, it often happens that, on raising the fire in order to bring the mixture into fusion, the hissing suddenly begins again, and is very loud. In that case all the apertures of the furnace must immediately be shut close, in order to choak and suffocate the fire: for, if this be neglected, the matter in the crucible will swell up, make its way through the luting of the juncture, nay, push up the cover, and run over. This accident is to be apprehended during the first five or six minutes after you raise the fire in order to melt the mixture. This effusion of the matter is accompanied with a dull flame, a thick, grey and yellow smoke, and a noise like that of some boiling liquor. When you observe these several phenomena you may be sure the matter is run out of the crucible, either in the manner above described, or by making its way through some cracks in the vessel, and consequently that the operation is spoiled.

Moreover, this event infallibly follows whenever a bit of coal happens to fall into the crucible; and this is one reason why it is necessary to cover it.

You may be certain that the operation hath succeeded if the scoria be smooth when cold, and have not in part escaped through the lute; if the Lead be not dispersed in globules through the whole mass of the matter contained in the crucible, but is, on the  
contrary,



contrary, collected at the bottom, in the form of a solid Regulus, not very shining, but of a bluish cast, and ductile. Moreover the scoria ought, in the present case, to be hard and black, and should not appear full of holes like a sieve, except only in that part which was contiguous to the Salt.

Here it is proper to observe that the Sea-salt doth not mix with the scoria, but floats upon it. After the operation it is black; which colour it gets, no doubt, from the charred parts of the flux. The absence of these signs shews the operation to have miscarried.

When the ore to be smelted is pyritose and refractory, it may be roasted at first with a much stronger degree of fire than is used for ores that are fusible; because the martial earth, and the unmetallic earth, which are always mixed in pyritose matters, hinder it from growing readily soft in the fire. Besides, such an ore requires a greater quantity of the black flux and of borax to be mixed with it, and a higher degree of fire to fuse it.

It is generally needless to mix iron filings with this sort of ore; because the martial earth, with which pyritose matters are always accompanied, is reduced during the operation by the help of the black flux, which for that purpose is mixed with it in a large proportion, and furnishes a quantity of iron sufficient to absorb the heterogeneous minerals mixed with the Lead.

Yet, if it should be observed that the pyrites which accompany the Lead ore are arsenical, then, as such pyrites contain but a small quantity of ferruginous earth, iron filings must be added; which are, on this occasion, so much the more necessary for absorbing the Arsenic, as this mineral remains in part confounded with the ore, is reduced to a Regulus during the operation, unites with the Lead, and  
destroys

destroys a great deal of it by procuring its vitrification.

The Lead obtained from such pyritose ores is commonly not very pure; it is blackish and scarce ductile; qualities communicated to it by a small mixture of Copper in the pyrites, which always contain more or less thereof. We shall presently shew the method of separating Lead from Copper.

Lead ore may also be reduced by melting it amidst coals. For that purpose first kindle a fire in the furnace in which you intend to melt your ore; then put a layer of your ore immediately upon the lighted coals, and cover it with another layer of coals.

Though the melting furnace used for this operation be capable of giving a considerable heat, yet it is necessary further to increase the force of the fire by the means of a good pair of perpetual bellows, which will produce an effect like that of a forge. The ore melts, the earth of the Lead unites with the phlogiston of the coals, and so is reduced to metal, which runs through the coals, and falls into an earthen vessel placed at the bottom of the furnace to receive it. Care must be taken to keep this vessel well filled with charcoal-dust, to the end that the Lead may be in no danger of calcination while it continues there; the charcoal-dust constantly furnishing it with phlogiston to preserve its metalline form.

The earthy and stony matters that accompany the ore are scorified by this fusion, just as they are by the other which is performed in a close vessel. With regard to the Sulphur and Arsenic, they are supposed to have been first accurately separated from the ore by roasting. This is the method commonly employed for smelting Lead ore at the works.

## PROCESS II.

*To separate Lead from Copper.*

**W**ITH luting earth and charcoal-dust make a flat vessel, widening upwards, and large enough to contain your metalline mass. Set it shelving downwards from the back towards the fore-part; and in the fore-part, at the bottom, make a little gutter communicating with another vessel of the same nature, placed near the former, and a little lower. Let the mouth of the gutter within side the upper vessel be narrowed, by means of a small iron plate fixed across it, while the loam is yet soft; so as to leave a very small aperture, in the lower part of this canal, sufficient to discharge the Lead as it melts. Dry the whole by placing lighted coals around it.

When this apparatus is dry, put your mixed mass of Copper and Lead into the upper vessel: both in that, and in the other vessel, light a very gentle fire of wood or charcoal, so as not to exceed the degree of heat necessary to melt Lead. In such a degree of heat the lead contained in the mixed mass will melt, and you will see it run out of the upper vessel into the lower, at the bottom of which it will unite into a *Regulus*. When in this degree of heat no more Lead flows, increase the fire a little, so as to make the vessel moderately red.

When no more will run, collect the Lead contained in the lower vessel. Melt it over again in an iron ladle, with a degree of fire sufficient to make the ladle red; throw into it a little tallow or pitch, and while it burns keep stirring the metal, in order to reduce any part of it that may be calcined. Remove the pellicle or thin crust which will form on the surface; squeeze out all the Lead it contains, and then put it to the mass of Copper left in the upper vessel.



vessel. Check the fire, and in the same manner take off a second skin that will form on the surface of the Lead. Lastly, when the metal is ready to fix, take off the skin that will then appear on it. The Lead remaining after this will be very pure, and free from all alloy of Copper.

With regard to the Copper itself, you will find it in the upper vessel covered with a thin coat of Lead: and if the Lead mixed with it was in the proportion of a fourth or a fifth part only, and the fire applied was gentle and slow, it will retain nearly the same form after the operation that the mixed mass had before.

### OBSERVATIONS.

LEAD frequently remains mixed with Copper after the reduction of its ore, especially if the ore was pyritose. Tho' Copper be a much more beautiful and more ductile metal than Lead, yet the latter by being alloyed with the former is rendered eager and brittle. This bad quality is easily discovered by the eye on breaking it: for the surface of the broken part appears all granulated; whereas when it is pure it is more evenly, and resembles a congeries of solid angles. If the Lead be alloyed with a considerable quantity of Copper, its colour hath a yellowish cast.

Considering the bad qualities which Copper communicates to Lead, it is necessary to separate these two metals from each other. The method above laid down is the simplest and the best. It is founded on two properties belonging to Lead: the first is that of being much more fusible than Copper; so that it will melt and run in a degree of heat that is not capable of making the Copper even red-hot, which yet is very far from being able to melt it: the second is, that Lead, though it hath an affinity with Copper, and unites very perfectly therewith, yet is not able to dissolve it without a greater heat

than the degree barely necessary to fuse Lead. Hence it comes that Lead may be melted in a Copper vessel, provided no greater degree of heat be applied than that purpose requires. But when the Lead becomes so hot as to be red, fume and boil, it instantly begins to dissolve the Copper. For this reason, it is essential to the success of our operation that a moderate degree of heat only be applied, and no greater than is requisite to keep the Lead in fusion.

Charcoal-dust is made an ingredient in the composition of the vessels used on this occasion, in order to prevent the calcination of the Lead.

The iron plate, with which the entrance of the gutter within the upper vessel is narrowed, serves to prevent the larger pieces of Copper, which the Lead may carry along with it, from passing through: it stops them, and allows the Lead to run off alone.

But as these parcels of Copper may entirely choak the passage, care must be taken, when any happen to be stoppt, to remove them from the entrance of the gutter, and push them back into the middle of the vessel. It is also necessary to observe whether or no the Lead fixes any where in the passage; and, if it does, the heat of that part must be increased, in order to melt it and make it run off.

Notwithstanding all the precautions that can be taken, to hinder the melted Lead from carrying off any Copper with it, it is impossible to prevent this inconvenience entirely: and therefore the Lead is melted over again, in order to separate the small portion of Copper with which it is still adulterated.

As Copper is much lighter than Lead; if these two metals happen to be so blended together that the Copper, without being in fusion and dissolved by the Lead, is only interposed between the parts of the melted Lead, so as to swim therein, it is then precisely in the case of a solid body plunged into a fluid heavier than itself, and must rise to the surface,

like

like wood thrown into water. It is proper to burn some inflammable matter on this melted Lead, in order to reduce such parts thereof as are constantly calcining on its surface while it is in fusion; for without this precaution they would be taken off together with the Copper.

The Copper remaining after this separation is, as we took notice before, still mixed with a little Lead. If you desire to separate it entirely therefrom, you must put it into a cupel, and expose it under the muffle to such a degree of fire as may convert all the Lead into litharge. This cannot be so done but that some of the Copper also will be scorified by the heat of the fire, and by the action of the Lead: but as there is a very great difference between the facility and readiness with which these two metals calcine, the portion of Copper that is calcined, while the whole Lead is turning into litharge, is scarce worth considering.

The Lead, though carefully separated from the Copper by the process here delivered, is not yet absolutely pure: sometimes it is alloyed with Gold, and almost always contains some Silver. If you would free the Lead as much as possible from any mixture of these two metals, you must convert it into glass, separate the remaining bead, and afterwards reduce this glass of Lead. But, as these two perfect metals are of no prejudice to the Lead, it is not usual to separate them from it, unless they be in a sufficient proportion to defray the charge, and produce some profit besides.

When we examine by the cupel the just proportion of Gold and Silver that an ore or a mixed metalline mass will yield, we make a previous assay of the Lead to be employed in the operation, and afterwards, in our estimate, deduct a proper allowance for the quantity of fine metal due to the Lead made use of.



## PROCESS III.

*The Calcination of Lead.*

**T**AKE what quantity of Lead you please; melt it in one or more unglazed earthen pans: a dark grey powder will be found on its surface. Keep stirring the metal incessantly till it be wholly converted into such a powder, which is the *Calx of Lead*.

## OBSERVATIONS.

As Lead is a very fusible metal, and in that respect greatly resembles Tin, most of the observations we made on the calcination of Tin may be applied here.

In the calcination of all metals, and particularly in this of Lead, there appears a singular phenomenon which is not easily accounted for. It is this: though these matters lose a great deal of their substance, either by the dissipation of their phlogiston, or because some of the metal, perhaps, exhales in vapours, yet when the calcination is over their calxes are found to be increased in weight, and this increase is very considerable. An hundred pounds of Lead, for example, converted into Minium, which is nothing but a calx of Lead brought to a red colour by continuing the calcination, are found to gain ten pounds weight; so that for an hundred pounds of Lead we have one hundred and ten pounds of Minium: a prodigious and almost incredible augmentation, if it be considered that, far from adding any thing to the Lead, we have on the contrary dissipated part of it.

To account for this phenomenon Natural Philosophers and Chymists have invented several ingenious hypotheses, but none of them entirely satisfactory.

As

As we have no established theory to proceed upon, we shall not undertake to explain this extraordinary fact.

## P R O C E S S IV.

*To prepare Glass of Lead.*

**T**AKE two parts of Litharge, and one part of pure crystalline Sand; mingle them together as exactly as possible, adding a little Nitre and Sea-salt: put this mixture into a crucible of the most solid and most compact earth. Shut the crucible with a cover that may perfectly close it.

Set the crucible thus prepared in a melting furnace; fill the furnace with coals; light the fire gradually, so that the whole may be slowly heated: then raise the fire so as to make the crucible very red, and bring the matter it contains into fusion; keep it thus melted for a quarter of an hour.

Then take the crucible out of the furnace, and break it: in the bottom thereof you will most commonly find a small button of Lead, and over it a transparent Glass, of a yellow colour nearly resembling that of amber. Separate this Glass from the little button of metal, and from the saline matters which you will find above it.

## O B S E R V A T I O N S.

PURE Lead, being exposed to a strong fire without any additament, turns to Litharge; which is a scaly sort of substance, more or less yellowish, shining, and soft to the touch. This is the first advance to the Vitrification of Lead. The large refineries of Gold and Silver by the means of Lead furnish a great quantity of this material. It is sometimes whitish, and is then called *Litharge of Silver*; some-

times yellow, and then bears the name of *Litharge of Gold*. The difference of its colour depends on the degree of fire it hath undergone, and on the metalline substances vitrified with it.

Litharge alone is very fusible, and being exposed to the fire is easily converted into Glass: but this Glass of Lead, made without additament, is so active, so penetrating, and so apt to swell, that it can scarcely be made use of when pure. We are obliged in some sort to clog it, by uniting it with some vitrifiable matter that is not so subtile, such as Sand; and it is for this reason, not to render the mixture more fusible, that we have directed the addition of one third part of Sand to two thirds of Litharge.

The Nitre and Sea-salt, prescribed as ingredients in the mixture, are designed to procure an equal fusion of the whole. For, as the Sand is lighter and less fusible than the Litharge, it will partly rise towards the upper part of the crucible when that matter first begins to flow; in consequence whereof the contents of the upper part will be much more difficult to melt, and form a Glass much more compact than that below: but the Nitre and Sea-salt possessing the upper part of the crucible, because they are still lighter than the Sand, and being in their own nature very efficacious fluxes, on account of their great fusibility, they quickly bring about the fusion of those particles of Sand, which, having escaped the action of the Litharge, may have risen unvitified to its surface.

The most difficult thing to procure, and yet the most necessary to the success of this operation, is a crucible of earth so firm and compact as not to be penetrated by the Glass of Lead, which corrodes and makes its way through every thing.

The precaution of chusing a crucible, that shall contain a good deal more than the matter to be vitrified,



trified, is a necessary one, because Litharge and Glass of Lead are very apt to swell.

The rule to keep the crucible close shut is also indispensably necessary, to prevent any bit of charcoal, or other inflammable-matter, from falling into it: for when this happens it occasions a reduction of the Lead, which is always attended with a sort of effervescence, and such a considerable heaving, that commonly most of the mixture runs over the crucible. For the same reason it is very proper, before you expose the mixture to the fire, to examine whether or no it contains any matter capable of furnishing a phlogiston during the operation; and if it does, to remove that matter with great care.

The little button of Lead, found at the bottom of the crucible after the operation, comes from a small portion of Lead that is commonly left in Litharge, unless you prepare it carefully yourself, and do not take it from the fire till you are sure of having destroyed all the Lead. Besides, this small portion of Lead can be of no prejudice to the operation, because it cannot communicate its phlogiston to the rest of the matter.

The revivifying of Litharge, of the Calx, and of the Glass of Lead, may be obtained by the same processes as the reduction of its ore.

## P R O C E S S V.

*Lead dissolved by the Nitrous Acid.*

**P**UT into a matrafs some *Aqua Fortis* precipitated like that used to dissolve Silver; weaken it by mixing therewith an equal quantity of common water; set the matrafs in a hot sand-bath; throw into it, little by little, small bits of Lead, till you see that no more will dissolve. *Aqua Fortis* thus lowered will dissolve about a fourth of its weight of Lead.

There is gradually formed upon the Lead, as it dissolves, first a grey powder, and afterwards a white crust, which at last hinder the solvent from acting on the remaining part of the metal; and therefore the liquor should be made to boil, and the vessel should be shaken to remove those impediments, by which means all the Lead will be dissolved.

### OBSERVATIONS.

LEAD very much resembles Silver, with respect to the phenomena which attend its dissolution in Acids. For example, the Nitrous Acid must be very pure and uncontaminated with the Vitriolic or Marine Acid, to qualify it for keeping the Lead in solution: for, if it be mixed with either the one or the other of these Acids, the Lead will precipitate in the form of a white powder as fast as it dissolves; which is just the case with Silver.

If the Vitriolic Acid be mixed with the Nitrous, the precipitate will be a combination of the Vitriolic Acid with Lead; that is, a Neutral Metallic Salt, or Vitriol of Lead. If the Acid of Sea-salt be mixed therewith, the precipitate will be a *Plumbum corneum*; that is, a Metallic Salt resembling the *Luna cornea*.

When all the Lead is dissolved as above described, the liquor appears milky. If it be kept warm over the fire till little crystals begin to appear on its surface, and afterwards left to stand quiet, in a certain time there will be found at the bottom a greyish powder, which being tried on Gold is Mercurial enough to whiten it. Little globules of Quick-silver are even discernible in it.

We owe this observation, together with this manner of proving the existence of Mercury in Lead, and of procuring it from thence, to M. Grosse, who hath given an account of his process in the Memoirs  
of

of the Academy of Sciences, from whence we have copied the description of the operation in hand.

The solution being quickly poured off by inclination from the grey mercurial precipitate is still milky, and deposits another white sediment. When this second precipitate falls the liquor becomes clear and limpid, and is then of a fine yellow colour, like a solution of Gold. On this gold-coloured solution, and on the two precipitates above-mentioned, M. Grosse made several observations, the chief of which we shall here insert.

The yellow liquor affects the tongue at first with a taste of sweetness; but afterwards vellicates it very smartly, and leaves on it a strong sensation of acrimony, which continues for a long time.

Alkalis precipitate the Lead suspended in this liquor, just as they do all other metals dissolved by Acids; and this precipitate of Lead is white.

Sea-salt, or Spirit of Salt, separates the Lead from its solvent, and precipitates it, as we observed before, into a *Plumbum corneum*: but this precipitate differs from the *Luna cornea*, as being very soluble in water; whereas the *Luna cornea* will not dissolve in it at all; or at least dissolves therein with great difficulty, and in a very small quantity. This *Plumbum corneum* dissolved in water is again precipitated by the Vitriolic Acid. M. Grosse observes that this forms an exception to the eighth column of Mr. Geoffroy's Table of affinities; in which the Acid of Sea-salt is marked as having a greater affinity than any other Acid with Metallic substances.

Our solution of Lead is also precipitated in a white powder by several Neutral Salts; such as Vitriolated Tartar, Alum, and common Vitriol. It is by the means of double affinities that the Neutral Salts effect this precipitation.

Even pure water alone is capable of precipitating the Lead of our solution, by weakening the Acid,  
and



and thereby disabling it from keeping the metal suspended.

Lastly, as all the solutions of metals in Acids are nothing but Neutral metallic Salts in a fluid form, so if the solution of Lead be evaporated over the fire, it will shoot into very beautiful crystals, about the bigness of hemp-seed, shaped like regular pyramids having square bases. These crystals are yellowish, and have a sweet saccharine taste: but what is most singular in them is, that, as they consist of the Nitrous Acid combined with Lead, which manifestly contains a great deal of phlogiston, they constitute a Nitrous Metallic Salt, which has the property of deflagrating in a crucible, without the addition of any other inflammable matter. It is extremely hard to dissolve this Salt in water.

The grey mercurial precipitate which whitens Gold, and in which little globules of running Mercury are perceivable, is far from being pure Mercury. This metallic substance makes but a small part thereof: for it is an assemblage 1. of little crystals of the same nature with those afforded by the evaporated solution; 2. of a portion of the white matter, or powder, which renders the solution milky; 3. of a grey powder which M. Grosse considers as the only mercurial part; 4. and lastly, of little particles of Lead that have escaped the action of the solvent; especially if a little more Lead than the Acid is capable of dissolving were added with a view to saturate it entirely, as in the present process.

By means of motion and heat the small parcels of Mercury may be amalgamated with the Lead.

That Mercury should be found intire and in globules in the Spirit of Nitre, which very easily dissolves that metallic substance, will not be surprizing to those who reflect that, in the present case, the Acid is saturated with Lead, with which it has a greater affinity than with Mercury; as appears by

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M. Geoffroy's Table of Affinities, where, in the column that hath the Nitrous Acid at top, Lead is placed above Mercury. Agreeably to this, if Lead be presented to a solution of Mercury in Spirit of Nitre, the Lead will be dissolved, and as the dissolution thereof advances the Mercury will precipitate.

Hence it appears that, in order to find any Mercury in the spontaneous precipitate of Lead dissolved by the Nitrous Acid, it is necessary that the Acid be entirely saturated with Lead; or else that portion of the Acid which remains unsaturated will dissolve the Mercury.

With regard to the white powder that renders the solution milky, and afterwards precipitates, it is nothing but a portion of the Lead, which, not being intimately united with the Acid, falls in part of its own accord. It is a sort of calx of Lead, which being exposed to the fire becomes partly glass, and partly Lead, because it still contains some of its phlogiston.

## CH A P. VII.

### *Of* M E R C U R Y.

#### P R O C E S S I.

*To extract Mercury from its Ore, or to revivify it from Cinabar.*

**P**ULVERIZE the Cinabar from which you would extract the Mercury; with this powder mix an equal part of clean iron filings; put the mixture into a retort of glass or iron, leaving at least one third part thereof empty. Set the retort thus prepared

prepared in a sand-bath, so that its body may be quite buried in the sand, and its neck decline considerably downwards: fit on a receiver half filled with water, and let the nose of the retort enter about half an inch into the water.

Heat the vessels so as to make the retort moderately red. The Mercury will rise in vapours, which will condense into little drops, and fall into the water in the receiver. When you see that nothing more comes over with this degree of heat, increase it, in order to raise what Mercury may still be left. When all the Mercury is thus brought over, take off the receiver, pour out the water contained in it, and collect the Mercury.

### OBSERVATIONS.

MERCURY is never mineralized in the bowels of the earth by any thing but Sulphur; with which it forms a compound of a brownish red colour, known by the name of *Cinabar*.

Sometimes it is only mixed with earthy and stony matters that contain no Sulphur; but as this metallic substance is never destitute of its phlogiston, it then has its metalline form and properties. When it is found in this condition, nothing is more easy than to separate it from those heterogeneous matters. For that purpose no more is requisite than to distill the whole with a fire strong enough to raise the Mercury in vapours. This mineral is volatile; the earthy and stony matters are fixed; and a certain degree of heat will effect a complete separation of what is volatile from what is fixed.

This is not the case when Mercury is combined with Sulphur: for this latter mineral is volatile as well as Mercury; and the compound resulting from the union of them both is also volatile: so that if *Cinabar* were exposed to the fire in close vessels,



as it must be to save the Mercury, it would be sublimed in substance, without being decomposed at all.

In order therefore to separate these two substances from each other, we must have recourse to the interposition of some third, which hath a greater affinity with one of them than the other hath, and no affinity with that other.

Iron hath all the conditions requisite for this purpose; seeing it hath, as may be seen in the Table, a much greater affinity with Sulphur than Mercury hath, and is incapable of contracting any union with Mercury.

Iron, however, is not the only substance that may be employed on this occasion: Fixed Alkalis, Absorbent earths, Copper, Lead, Silver, Regulus of Antimony, have all, as well as Iron, a greater affinity than Mercury with Sulphur. Nay, several of these substances, namely, the saline and earthy Alkalis, as well as Regulus of Antimony, cannot contract any union with Mercury: the rest, to wit, Copper, Lead, and Silver, are indeed capable of amalgamating with Mercury; but then the union which these metals contract with the Sulphur prevents it; and even tho' they should unite with this metallic substance, the degree of heat to which the whole mixture is exposed would soon carry up the Mercury, and separate it with ease from those fixed substances.

In this distillation the same cautions must be observed as in all others: that is, the vessels must be slowly heated, especially if a glass retort be used; the fire must be raised by degrees, and a much stronger one applied at last than at first. This operation particularly requires a very strong degree of fire, when there is but a small quantity of Mercury left.

After the operation there remains in the retort a compound of Iron and Sulphur, which may easily

be converted into a *crocus*, by calcining it and burning away the Sulphur.

If a Fixed Alkali be employed, a Liver of Sulphur will be found in the retort after the distillation.

If the Cinabar from which you extract the Mercurial be good, you will generally obtain seven eighths of its weight in Quick-silver.

In the present operation it is not necessary to lute on the receiver, because the water, in which the nose of the retort is plunged, is sufficient to fix the Mercurial vapours. In case the Cinabar, from which you intend to separate the Mercury, be mixed with a great quantity of heterogeneous, but fixed, matters, such as earths, stones, &c. it may be separated from them by subliming it with a proper degree of heat, because it is volatile.

The vapours of Mercury are prejudicial, and may excite a salivation, tremors, and palsies; they should therefore be always avoided by such as work on this mineral.

The oldest and richest mine of Mercury is that of Almaden in Spain. It is a singular property of that mine that, though the Mercury found in it is combined with Sulphur, and in the form of Cinabar, yet no additament is required to procure the separation of these two; the earthy and stony matter, with which the particles of the ore are incorporated, being itself an excellent absorbent of Sulphur.

In the Quick-silverworks carried on at this mine they make no use of retorts. They place lumps of the ore on an iron grate, which stands immediately over the furnace. The furnaces which serve for this operation are closed at the top by a sort of dome, behind which stands the shaft of a chimney that communicates with the fire-place, and gives vent to the smoke. These furnaces have in their fore-side sixteen apertures, to each of which is luted an aludel in a horizontal position, communicating with a  
long

long row of other aludels placed likewise in an horizontal direction ; which aludels so connected together form one long pipe or canal, the further end whereof opens into a chamber destined to receive and condense all the mercurial vapours. These rows of aludels are supported from end to end by a terrass, which runs from the body of the building, wherein the furnaces are erected, to that where the chambers are built that perform the office of receivers.

This is a very ingenious contrivance, and saves much labour, expence, and trouble, that would be unavoidable if retorts were employed.

That part of the furnace which contains the lumps of ore, serves for the body of the retort; the row of aludels for its neck; and the little chambers in which these canals terminate are actual receivers. The terrass of communication, which reaches from the one building to the other, is formed of two inclined planes, the lower edges of which, meeting in the middle of the terrass, rise from thence insensibly ; the one quite to the building where the furnaces are, and the other to that which forms the recipient chambers. By this means, when any Mercury escapes through the joints of the aludels, it naturally runs down along these inclined planes, and so is collected in the middle of the terrass, where the inferior sides of the planes meeting together form a sort of canal, out of which it is easily taken up.

The celebrated M. de Jussieu having viewed the whole himself, in a journey he made to this mine, furnished us with a description of the work.



## PROCESS II.

*To give Mercury, by the action of Fire, the appearance of a Metalline Calx.*

**P**UT Mercury into several little glass matrasses with long and narrow necks. Stop the matrasses with a little paper, to prevent any dirt from falling into them. Set them all in one sand-bath, so that they may be surrounded with sand as high as two thirds of their length. Apply the strongest degree of heat that Mercury can bear without subliming: continue this heat without interruption, till all the Mercury be turned to red powder. The operation lasts about three months.

## OBSERVATIONS.

MERCURY treated according to the process here delivered hath all the appearance of a metalline calx, but it hath no more: for, if it be exposed to a pretty strong degree of fire, it sublimes, and is wholly reduced to running Mercury, without the addition of any other inflammable matter; which proves that during this long calcination it lost none of its phlogiston.

The volatile nature of Mercury, which permits it not to bear a heat of any strength without subliming, prevents our examining all the effects that fire is capable of producing on it. Yet there is reason to believe that, as this metallic substance resembles the perfect metals in its weight, its splendour, and a brilliancy which resists all the impressions of the air without alteration, it would like them be unchangeable by the greatest force of fire, if it were fixed enough to bear it.

In order to give Mercury the form of a metalline calx, it must necessarily be exposed for about three months

months together, to the utmost heat it can bear without subliming, as is above directed. Boerhaave kept it digesting in a less heat for fifteen years successively, both in open and in close vessels, without observing it to suffer the least change; except that there was formed upon its surface a small quantity of a black powder, which was reduced to running Mercury by trituration alone.

Mercury thus converted to a red powder is known in chymistry and medicine by the name of *Mercury precipitated per se*: a title proper enough, as it is actually reduced to the form of a precipitate, and that without any additament; but very improper on the other hand, considering that in reality this Mercury is not a precipitate, as not having been separated from any menstruum in which it was dissolved.

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### P R O C E S S III.

*To dissolve Mercury in the Vitriolic Acid. Turbith Mineral.*

**P**UT Mercury into a glass retort, and pour on it thrice its weight of good Oil of Vitriol. Set the retort in a sand-bath; fit on a recipient; warm the bath by degrees till the liquor just simmers. With this heat the Mercury will begin to dissolve. Continue the fire in this degree till all the Mercury be dissolved.

### O B S E R V A T I O N S.

THE Vitriolic Acid dissolves Mercury pretty well: but for this purpose the Acid must be very hot, or even boil; and then too it is a very long time before the dissolution is completed. We have directed the operation to be performed in a retort; because this solution is usually employed to make another preparation called *Turbith Mineral*, which requires that as much as possible of the Acid solvent be abstracted by

VOL. I. D d distil-

distillation. Having therefore dissolved your Mercury in the Vitriolic Acid, if you will now prepare the Turbith, you must, by continuing to heat the retort, drive over all the liquor into the receiver, and distill till nothing remains but a white powdery matter: then break the retort: pulverize its contents in a glass mortar, and thereon pour common water, which will immediately turn the white matter of a lemon colour; wash this yellow matter in five or six warm waters, and it will be what is called in medicine *Turbith Mineral*; that is, a combination of the Vitriolic Acid with Mercury, five or six grains whereof is a violent purgative, and also an emetick; qualities which it possesses in common with the Vegetable Turbith, whose name it hath therefore taken.

There rises out of the retort, both while the Mercury is dissolving, and while the solvent is abstracting, a weak Spirit of Vitriol; because a great part of the Acid remains united with the Quick-silver, which at last appears in the form of a white powder: so that if you do not incline to save the Acid which rises on this occasion, you may, instead of drawing off the liquor in a retort, evaporate it in a glass basin set on a sand-bath, which will be much sooner done.

It is very remarkable that, on this occasion, the Mercury may be exposed, without any danger of subliming, to a much greater heat than it is capable of bearing when not combined with the Vitriolic Acid; which shews that this Acid hath the property of fixing Mercury to a certain degree.

The white matter, that remains after the evaporation of the fluid, is one of the most violent corrosives, and would prove an actual poison if taken internally. By washing it several times in warm water it is freed from a great deal of its Acid, and so considerably sweetened. The proof is this; if the water used in washing the Turbith be evaporated,



rated, there remains after the evaporation a matter in form of a Salt, that being set in a cellar runs into a liquor called *Oil of Mercury*, which is a powerful corrosive. Several authors further direct Spirit of Wine to be burnt on the Turbith, to sweeten it still more.

If instead of washing the white matter that remains after the moisture is drawn off, fresh Oil of Vitriol be poured on it, and then abstracted as before; this treatment being repeated two or three times, there will at last remain in the retort a matter having the appearance of an oil, which resists the action of the fire, and cannot be desiccated: qualities which are owing to the great quantity of Acid particles thus united with the Mercury. This Oil of Mercury is one of the most violent corrosives. The Mercury may be separated therefrom, by precipitating it with an Alkali, or a metallic substance that hath more affinity than Mercury with the Vitriolic Acid: Iron, for instance, may be employed in this precipitation. Mercury thus separated from the Vitriolic Acid need only be distilled to recover the form of Quick-silver.

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#### P R O C E S S I V.

*To combine Mercury with Sulphur. Æthiops Mineral.*

**M**IX a dram of Sulphur with three drams of Quick-silver, by triturating the whole in a glass mortar with a glass pestle. By degrees, as you triturate, the Mercury will disappear and the matter will acquire a black colour. Continue the triture till you cannot perceive the least particle of running Mercury. The black matter you will then have in the mortar is known in medicine by the name of *Æthiops Mineral*. An *Æthiops* may also be made by fire in the following manner.

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In a shallow unglazed earthen pan melt one part of flowers of Sulphur: add three parts of running Mercury, making it fall into the pan in the form of small rain, by squeezing it through chamoy leather. Keep stirring the mixture with the shank of a tobacco-pipe all the while the Mercury is falling: you will see the matter grow thick and acquire a black colour. When the whole is thoroughly mixed, set fire to it with a match, and let as much of the Sulphur burn away as will flame.

### OBSERVATIONS.

MERCURY and Sulphur unite together with great ease; cold triture alone is sufficient to join them. By this means the Mercury is reduced into exceeding small atoms, and combines so perfectly with the Sulphur, that the least vestige thereof is not to be seen.

Sulphur is not the only matter which being rubbed with Mercury will destroy its form and fluidity: all fat substances that have any degree of consistence, such as the fat of animals, balsams, and resins, are capable of producing the same effect. This metallic substance, being triturated for some time in a mortar with these matters, becomes at last invisible, and communicates to them a black colour. When thus divided by the interposition of heterogeneous particles, it is said to be *Killed*. But Mercury doth not contract such an intimate union with these other matters as it doth with Sulphur.

The *Æthiops* prepared by fusion is a more perfect and accurate combination of Mercury and Sulphur than the other: for, the quantity of Sulphur directed to be used in making it being much greater than is absolutely necessary to fix the Mercury, the redundant Sulphur is destroyed by burning, and none left but what is most intimately united with the Mercury, and hindered by the union it hath

contracted with that metallic substance from being so easily consumed. The Æthiops therefore, which is prepared by fusion and burning the Sulphur, contains a much greater proportion of Mercury than that which is made by simple triture; so that in Medicine it ought to be prescribed in different cases, and in smaller doses.

If no more Sulphur than is just necessary to kill the Mercury be added to it at first, it will be difficult to obtain a perfect mixture; because that quantity is very small: it is better therefore to employ at once the quantity above directed.

## PROCESS V.

*To sublime the combination of Mercury and Sulphur into Cinabar.*

**G**RIND to powder Æthiops mineral prepared by fire. Put it into a cucurbit; fit thereto a head; place it in a sand-bath, and begin with applying such a degree of heat as is requisite to sublime Sulphur. A black matter will rise, and adhere to the sides of the vessel. When nothing more will rise with this degree of heat, raise the fire so as to make the sand and the bottom of the cucurbit red; and then the remaining matter will sublime in the form of a brownish red mass, which is true *Cinabar*.

## OBSERVATIONS.

ÆTHIOPS Mineral requires nothing but sublimation to become true *Cinabar*, like that found in Quick-silver mines: but our Æthiops contains still more Sulphur than ought to be in the composition of *Cinabar*; for which reason we have directed the degree of fire applied at first to be no greater than that which is capable of subliming Sulphur. As *Cinabar*, though consisting of Mercury and Sul-



phur, is yet much less volatile than either of these substances alone; which probably arises from the Vitriolic Acid contained in the Sulphur; therefore, if there be any redundant Sulphur in the Æthiops, which hath not contracted an intimate union with the Mercury, it will sublime by itself in this first degree of heat. Some mercurial particles also will rise with it, and give it a black colour.

Cinabar contains no more Sulphur than about a sixth or seventh part of its weight; so that, instead of employing the common Æthiops to make it, it would be better to prepare one on purpose that should contain much less Sulphur; because too much Sulphur prevents the success of the operation by blackening the Sublimate. Indeed in whatever manner you go about it, the Cinabar always appears black at first: but when it is well prepared, and contains no more than its due proportion of Sulphur, the blackness is only external. This black coat therefore may be taken off: and then the internal part will appear of a fine red, and, if sublimed a second time, will be very beautiful.

As artificial Cinabar hath the same properties with the native, it may be decomposed by the same means: so that, if you want to extract the Mercury out of it, recourse must be had to the process above delivered for working on Cinabar ores.

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## PROCESS VI.

*To dissolve Mercury in the Nitrous Acid. Sundry Mercurial Precipitates.*

**P**UT into a matraass the quantity of Mercury you intend to dissolve: pour on it an equal quantity of good Spirit of Nitre, and set the matraass in a sand-bath moderately heated. The Mercury will dissolve with the phenomena that usually attend the

the dissolutions of metals in this Acid. When the dissolution is completed let the liquor cool. You will know that the Acid is perfectly saturated, if there remain at the bottom of the vessel, notwithstanding the heat, a little globule of Mercury that will not dissolve.

## OBSERVATIONS.

MERCURY dissolves in the Nitrous Acid with much more facility, and in much greater quantity, than in the Vitriolic; so that it is not necessary, on this occasion to make the liquor boil. This solution when cold yields crystals, which are a Nitrous Mercurial Salt. If you desire to have a clear limpid solution of Mercury, you must employ an *Aqua Fortis* that is not tainted with the Vitriolic or Marine Acid: for, the affinity of these two Acids with Mercury being greater than that of the Nitrous Acid, they precipitate it in the form of a white powder, when they are mixed with the solvent.

Mercury thus precipitated in a white powder, out of a solution thereof in the Spirit of Nitre, is used in Medicine. To obtain this precipitate, which is known by the name of the *White Precipitate*, Sea-salt dissolved in water together with a little Sal Ammoniac is used; and the precipitate is washed several times in pure water, without which precaution it would be corrosive, on account of the great quantity of the Marine Acid which it would contain.

The preparation known by the name of *Red Precipitate* is also obtained from our solution of Mercury in Spirit of Nitre. It is made by abstracting all the moisture of the solution, either by distillation in a retort, or by evaporation in a glass basin set on a sand-bath. When it begins to grow dry it appears like a white ponderous mass. Then the fire is made strong enough to drive off almost all the Nitrous Acid, which, being now concentrated, rises in the

form of red vapours. If these vapours be caught in a receiver, they condense into a liquor, which is a very strong and vastly smoking Spirit of Nitre.

By degrees, as the Nitrous Acid is forced up by the fire, the mercurial mass loses its white colour, and becomes first yellow, and at last very red. When it is become entirely of this last colour the operation is finished. The red mass remaining is a Mercury that contains but very little Acid, in comparison of what it did while it was white: and indeed the first white mass is such a violent corrosive, that it cannot be used in Medicine; whereas, when it is become red, it makes an excellent escharotic, which those who know how to use it properly apply with very great success, particularly to venereal ulcers.

This preparation is very improperly called a *Precipitate*: for the Mercury is not separated from the Spirit of Nitre by the interposition of any other substance, but only by evaporating the Acid. It is also called *Arcanum Corallinum*.

It must be observed that Mercury, by its union with the Nitrous Acid, acquires a certain degree of fixity: for the red precipitate is capable of sustaining, without being volatilized, a stronger degree of heat than pure Mercury can; which, as we observed before, is the property of Turbith mineral also.

## PROCESS VII.

*To combine Mercury with the Acid of Sea-salt.  
Corrosive Sublimate.*

**E**VAPORATE a solution of Mercury in the Nitrous Acid till there remain only a white powder, as mentioned in our observations on the preceding process. With this powder mix as much Green Vitriol calcined to whiteness, and as much decrepitated Sea-salt, as there was Mercury in the solution.



solution. Triturate the whole carefully in a glass mortar. Put this mixture into a matraass, so that two thirds thereof may remain empty, having first cut off the neck to half its length : or instead thereof you may use an apothecary's phial. Set your vessel in a sand-bath, and put sand round it as high as the contents reach. Apply a moderate fire at first, and raise it by slow degrees. Vapours will begin to ascend. Continue the fire in the same degree till they cease. Then stop the mouth of the vessel with paper, and increase the fire till the bottom of the sand-bath be red-hot. With this degree of heat a Sublimate will rise, and adhere to the inside and upper part of the vessel, in the form of white, semi-transparent crystals. Keep up the fire to the same degree till nothing more will sublime. Then let the vessel cool ; break it, and take out what is sublimed, which is *Corrosive Sublimate*.

## O B S E R V A T I O N S.

IN this operation the mineral Acids act, and are acted upon, in a remarkable manner. Every one of the three is at first neutralized, or united with a different basis; the Vitriolic being combined with Iron; the Nitrous with Mercury, forming therewith a Nitrous Mercurial Salt; and the Marine with its natural Alkaline basis. The Vitriolic and Nitrous Acids, which are united with metalline substances, being both stronger than the Acid of Sea-salt, strive to expel it from its basis, in order to combine with it themselves; but the Vitriolic Acid, being the strongest of the two, would take sole possession of this basis exclusive of the Nitrous, which would continue united with the Mercury, if the Marine Acid had not a greater affinity than the Nitrous with this metallic substance. This Acid therefore being expelled from its basis by the Vitriolic Acid, and so set at liberty, must unite with the Mercury, and separate the Nitrous Acid from it; which now hath no resource but to unite with the Iron deserted by

by the Vitriolic Acid. But as all these changes are brought about by the means of a considerable heat, and as the Nitrous Acid hath not a very firm connection with the Iron, it is driven off by the force of the fire; and this it is which we see rise in vapours during the operation. It also carries off with it some parts of the other two Acids, but in a very small quantity. After the operation, therefore there remains, 1. A combination of the Vitriolic Acid with the basis of Sea-salt; that is a Glauber's Salt: 2. A red martial earth, being that which was the basis of the Vitriol: these two substances are blended together, and remain at the bottom of the vessel because of their fixity: 3. A combination of the Marine Acid with Mercury; both of which being volatile, they ascend together into the upper part of the vessel, and there form a Corrosive Sublimate.

If we reflect on this process with attention, and recollect distinctly the affinities of the different substances employed in it, we shall perceive that it is not necessary to make use of all those matters, and that the operation would succeed though several of them were left out.

First, the Nitrous Acid may be omitted; since, as hath been shewn, it is not an ingredient in the Sublimate, but is dissipated in vapours during the operation. From an accurate mixture therefore of Vitriol, Sea-salt, and Mercury, a Corrosive Sublimate must be obtained: for as the Acid of the Vitriol will disengage the Acid of Sea-salt, the latter will be at liberty to combine with the Mercury, and so form the compound we are in quest of.

Secondly, if we make use of Mercury dissolved by the Nitrous Acid, we may omit the Vitriol; because the Nitrous Acid having a greater affinity than the Marine Acid itself with the basis of Sea-salt, and the Acid of Sea-salt having a greater affinity than the Nitrous Acid with Mercury, these two Acids will naturally make an exchange of the bases with  
which

which they are united: the Nitrous will lay hold on the basis of Sea-salt, and form a quadrangular Nitre, while the Marine Acid will join the Mercury, and with it form a Corrosive Sublimate.

Thirdly, instead of Sea-salt its Acid only may be employed; which being mixed with the solution of Mercury in the Spirit of Nitre, will, by virtue of its greater affinity with that metallic substance, separate it from the Nitrous Acid, unite with it, and form a white mercurial precipitate, which need only be sublimed to become the combination required.

Fourthly, instead of Mercury dissolved in the Nitrous Acid, Mercury dissolved by the Vitriolic Acid, or Turbith, may be used; only mixing Sea-salt therewith: for these two saline substances will mutually decompose each other, by virtue of the affinities of their Acids, and for the same reasons that Sea-salt and the Mercurial Nitrous Salt decompose each other. The Vitriolic Acid quits the Mercury with which it is combined, to unite with the basis of the Sea-salt; and the Acid of this Salt being expelled by the Vitriolic, combines with the Mercury, and consequently forms our Corrosive Sublimate. In this case a Glauber's Salt remains after the sublimation.

These several methods of preparing Corrosive Sublimate are never used, because each of them is attended with some inconvenience; such as requiring too long triture, yielding a Sublimate less corrosive than it should be, or a smaller quantity of it. We must, however, except the last; which was invented by the late Mr. Boulduc, of the Academy of Sciences, who found none of these inconveniences attending it\*.

Corrosive Sublimate may also be made only by mixing Mercury with Sea-salt, without any additament. This may appear surprizing when we consider that, as Acids have a greater affinity with Alka-

\* See the Memoirs of the Academy for 1730.



lis than with metallic substances, the Acid of Sea-salt ought not to quit its basis, which is Alkaline, to unite with Mercury.

In order to explain this phenomena it must be remembered that Sea-salt, when exposed to the fire without additament, suffers a little of its Acid to escape. Now this portion of the Marine Acid unites with the Mercury, and forms a Corrosive Sublimate. Moreover, as there is a pretty strong affinity between the Marine Acid and Mercury, this may help to detach from the Sea-salt a greater quantity of Acid than it would otherwise part with. Nevertheless the quantity of Sublimate obtained by this means is not considerable, nor is it very corrosive.

On this occasion we must also mention another combination of the Marine Acid with Mercury; which is made by mixing that metallic substance perfectly with Sal Ammoniac, by the means of triture. Mercury, like all other metals except Gold, possesses the property of decomposing Sal Ammoniac, separating the volatile Alkali which serves it for a basis, and combining, by the help of a very gentle heat, with its Acid, which is well known to be the same with that of Sea-salt. This decomposition of Sal Ammoniac, by the metalline substances, is a full exception to the first column of Mr. Geoffroy's Table of Affinities, and is the basis of several new medicines invented by the late Comte de la Garaye\*.

Corrosive Sublimate is the most violent and the most active of all corrosive poisons. It is never used in medicine, but in external applications. It is a powerful escharotic; it destroys proud flesh, and cleans old ulcers: but it must be used by those only who know how to apply it properly, and requires an able hand to manage it. It is not commonly applied by itself, but mixed in the proportion of half a dram

\* See the memoir given in by me on this subject to the Academy of Sciences in the *Memoires l'Academie* 1754.

to a pound of lime-water. This mixture is yellowish, and bears the name of *Aqua Phagedenica*.

Water dissolves Corrosive Sublimate, but in a small quantity. If a Fixed Alkali be mixed with this solution, the Mercury precipitates in the form of a red powder. If the precipitate be procured by a Volatile Alkali, it is white; if by Lime-water, it is yellow. This Mercurial Salt dissolves pretty easily in boiling Spirit of Wine.

## P R O C E S S VIII.

### *Sweet Sublimate.*

**T**AKE four parts of Corrosive Sublimate; pulverise it in a glass or marble mortar; add by little and little three parts of Mercury revived from Cinabar; triturate the whole carefully, till the Mercury be perfectly killed, so that no globule thereof can be perceived. The matter will then be grey. Put this powder into an apothecary's phial, or into a matrafs, whose neck is not above four or five inches long, leaving two-thirds thereof empty. Set the vessel in a sand-bath, and put sand round it to one third of its height. Apply a moderate fire at first; and afterwards raise it gradually till you perceive that the mixture sublimes. Keep it up to this degree till nothing more will rise, and then break the vessel. Reject, as useless, a small quantity of earth which you will find at the bottom; separate also what adheres to the neck of the vessel, and carefully collect the matter in the middle, which will be white. Pulverize it; sublime it a second time, in the same manner as before; and in the same manner separate the earthy matter left at the bottom of the vessel, and what you find sublimed into the neck. Pulverize, and sublime a third time, the white matter you last found in the middle.

dle. The white matter of this third sublimation is the *Sweet Sublimate*, called also *Aquila Alba*.

### OBSERVATIONS.

THE Acid of Sea-salt in the Corrosive Sublimate is very far from being perfectly saturated with Mercury; and thence comes the corrosive quality of this saline compound. But though Mercury, as appears by this combination, is capable of imbibing a much greater quantity of Acid than is necessary to dissolve it; nay, though it naturally takes up this superabundant quantity of Acid, yet it doth not follow from thence that this redundant Acid may not combine with Mercury to the point of perfect saturation, so as to lose its corrosive acidity.

This is the case in the operation here described. A fresh quantity of running Mercury is mixed with Corrosive Sublimate; and the fresh Mercury, combining with the super-abounding Acid, deprives the Sublimate of its acrimony, and forms a compound which comes much nearer the nature of a Neutral Metallic Salt.

Trituration alone is not sufficient to produce an union between the newly added Mercury and the Acid of the Corrosive Sublimate; because, generally speaking, the Acid of Sea-salt cannot dissolve Mercury without the help of a certain degree of heat, and unless it be reduced into vapours.

Thus, though the newly added Mercury becomes invisible by trituration and seems actually combined with the Corrosive Sublimate, yet the union is not intimate. There is only an interposition of parts, but no true dissolution of the newly added Mercury by the super-abundant Acid of the Corrosive Sublimate. For this reason the mixture must be sublimed; and by this sublimation only is the true union effected. Nor is one single sublimation sufficient: no less than three are necessary to deprive the Sublimate of the corrosive quality which renders



ders it poisonous. After the third sublimation, the Sublimate being put upon the tongue gives no considerable sensation of acrimony; nor doth it retain any more of its former activity than is requisite to make it a gentle purgative, when administered from six to thirty grains for a dose.

If a less quantity of Mercury than that above directed be mixed with the Corrosive Sublimate, the super-abundant Acid will not be sufficiently saturated; and the less Mercury is added, the more of its corrosive virtue will the Sublimate retain.

If, on the contrary, a greater quantity of Mercury be added, there will be more than the Acid can possibly dissolve, and the superfluous quantity will remain in its natural form of Quick-silver. It is better therefore to err in the excess than in the defect of the proportion of Mercury to be added; because the Corrosive Sublimate will take up no more than is necessary to dulcify it.

Part of the Acid of the Corrosive Sublimate is also dissipated in vapours during the operation; and it is necessary to allow room for these vapours to circulate, and a vent to give them passage, or else they will burst the vessels. These are our reasons for leaving an empty space in the subliming vessels, and for having their necks no more than five or six inches long.

The matter which sublimes into the neck of the vessel is always very acrid: for which reason it must be separated from the Sweet Sublimate. There remains also at the bottom of the matraass an earthy, reddish matter; which probably comes from the Vitriol employed in making the Corrosive Sublimate. This matter must likewise be rejected as useless after every sublimation.

## P R O C E S S IX.

*The Panacea of Mercury.*

**P**ULVERISE some Sweet Sublimate, and sublime it in the same manner as you did thrice before. Repeat this nine times. After these sublimations it will make no impression on the tongue. Then pour on it aromatic Spirit of Wine, and set the whole in digestion for eight days. After that decant the Spirit of Wine, and dry what remains, which is the *Panacea of Mercury*.

## O B S E R V A T I O N S.

THE great number of sublimations, which the Sweet Sublimate is made to undergo, sweeten it still more, and to such a degree that it leaves no sensation on the tongue, nor hath any purgative virtue.

The Spirit of Wine, in which it is digested after all the sublimations, is designed to blunt still more the sharpness of any acid particles that may not have been sufficiently dulcified by the preceding sublimations.

As Mercury is the specific remedy for venereal disorders, sundry preparations thereof have been attempted with a view to produce different effects. Sweet Sublimate is purgative; and for that reason is not quite proper for procuring a salivation, because it carries off the humours by stool. The Panacea of Mercury, which, on the contrary, is not purgative, may raise a salivation when taken inwardly.

END OF THE FIRST VOLUME.

# EXPLANATION OF THE PLATES.

## PLATE FIRST.

### FIG. I. *A Copper Alembic.*

- A. The Cucurbite or Body.
- B. The Neck.
- C. The Head.
- D. The Beak, Nose, or Spout.
- E. The Refrigeratory, or Cooler.
- F. Its Cock.
- G. The Receiver.

### FIG. II. *A Glass Alembic.*

- A. The Cucurbite.
- B. The Head.
- C. The Gutter within the Head.
- D. The Beak.

### FIG. III. *A long-necked Glass Alembic.*

- A. The Body of the Matrafs.
  - B. The Neck.
  - C. The Head.
- 

## PLATE SECOND.

### FIG. I. *A Glass Alembic of one Piece.*

- A. The Cucurbite.
- B. The Head.
- C. The Aperture in the Head.
- D. Its Stopple.
- E. The Mouth of the Cucurbite.



FIG. II. *A Pelican.*

- A. The Cucurbite.
- B. The Head.
- C. The Aperture in the Head, with its Stopple.
- D. D. The two curved Spouts.

FIG. III. *A Row of Aludels.*FIG. IV. *A Retort.*

- A. Its Bowl.
- B. Its Neck.

FIG. V. *An English Retort.*

## P L A T E   T H I R D .

FIG. I. *A Reverberating Furnace.*

- A. The Ash-hole Door.
- B. The Fire-place Door.
- C. C. C. C. Registers.
- D. The Dome, or Reverberatory.
- E. The Conical Funnel.
- F. The Retort in the Furnace.
- G. The Receiver.
- H. H. Iron Bars to sustain the Retort.

FIG. II. *The Conical Funnel by itself.*FIG. III. *Back View of a Muffle.*

- A. The bottom of the Muffle.
- B. Its Arch.
- C. C. C. Lateral apertures..

FIG. IV. *Fore View of a Muffle.*FIG. V. *A Melting Furnace.*

- A. A. The Base of the Furnace.
- B. The Ash-hole.
- C. D. The Grate for the Fire.

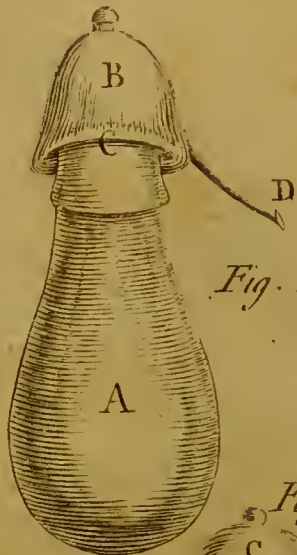
E. The



*Fig. 1.*



*Fig. 2.*



*Fig. 3.*





- E. The Fire-place.
  - F. G. H. Curvature of the inside of the upper part of the Fire-place.
  - I. The Shaft or Chimney.
- 

## PLATE FOURTH.

### *A Cupelling Furnace.*

- A. The Ash-hole.
- B. B. Its sliding Doors.
- C. The Fire-place.
- D. D. Its sliding Doors.
- E. F. Small apertures in the Sliders.
- G. G. Holes for Bars to bear the Muffles.
- H. H. H. Iron braces in the forepart of the Furnace, which form grooves for the Doors of the Fire-place and Ash-hole to slide in.
- I. The upper pyramidal part of the Furnace.
- K. An aperture therein for managing the Coals.
- L. The opening at top.
- M. The Pyramidal Cover.
- N. The Chimney or End of the Shaft, on which the conical Funnel may be fitted.
- O. O. O. O. Handles for moving the sliding Doors.
- P. P. Ears of the Pyramidal Cover.

N. B. The Furnaces, as represented in the two last Plates, are not in due proportion to each other. The Cupelling Furnace is much larger than it should be, with respect to the Melting Furnace. These dimensions are here given it, only that all its parts might be more distinctly expressed, than could have been done if we had made it less,



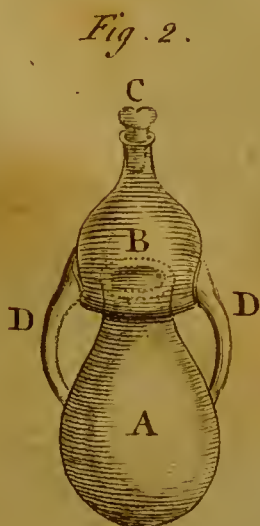


Fig. 3.



Fig. 4.

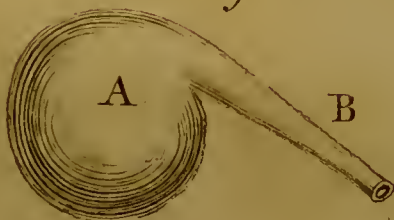


Fig. 5.

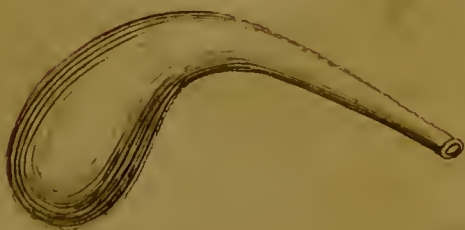








Fig. 1.

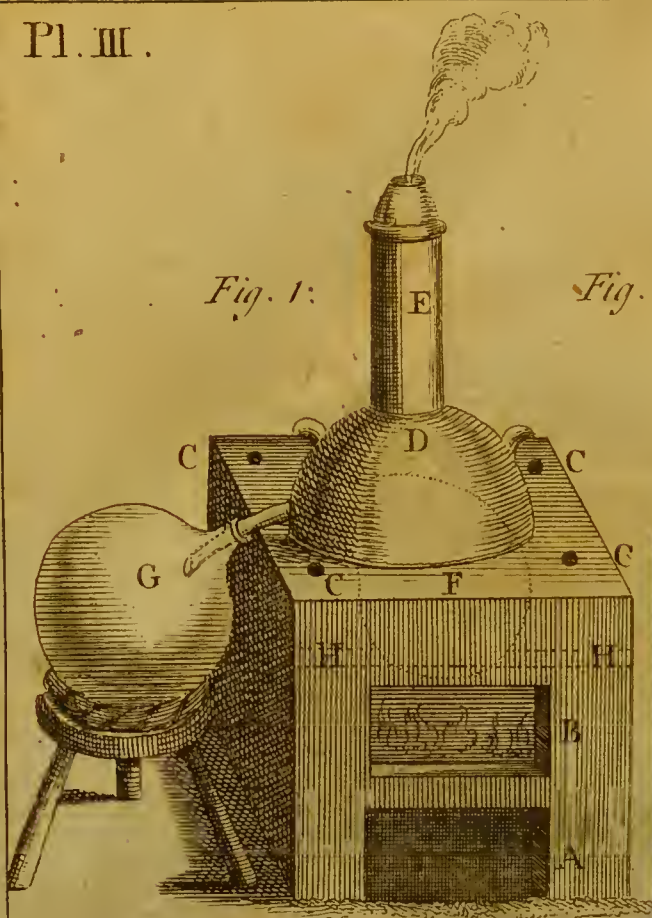


Fig. 2.



Fig. 5.



B Fig. 3.

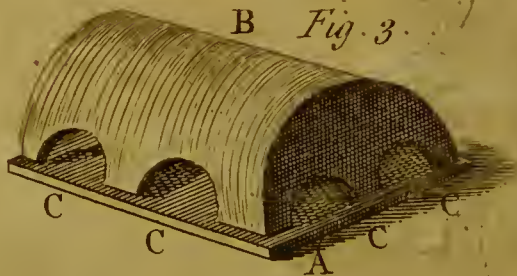
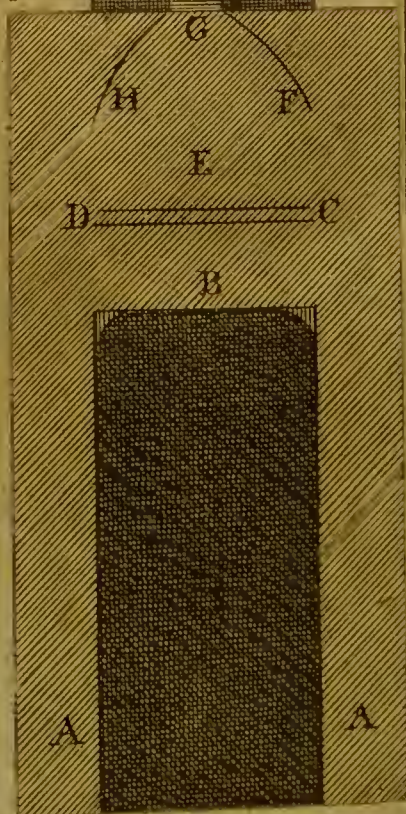
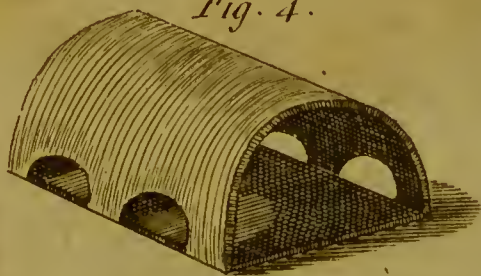
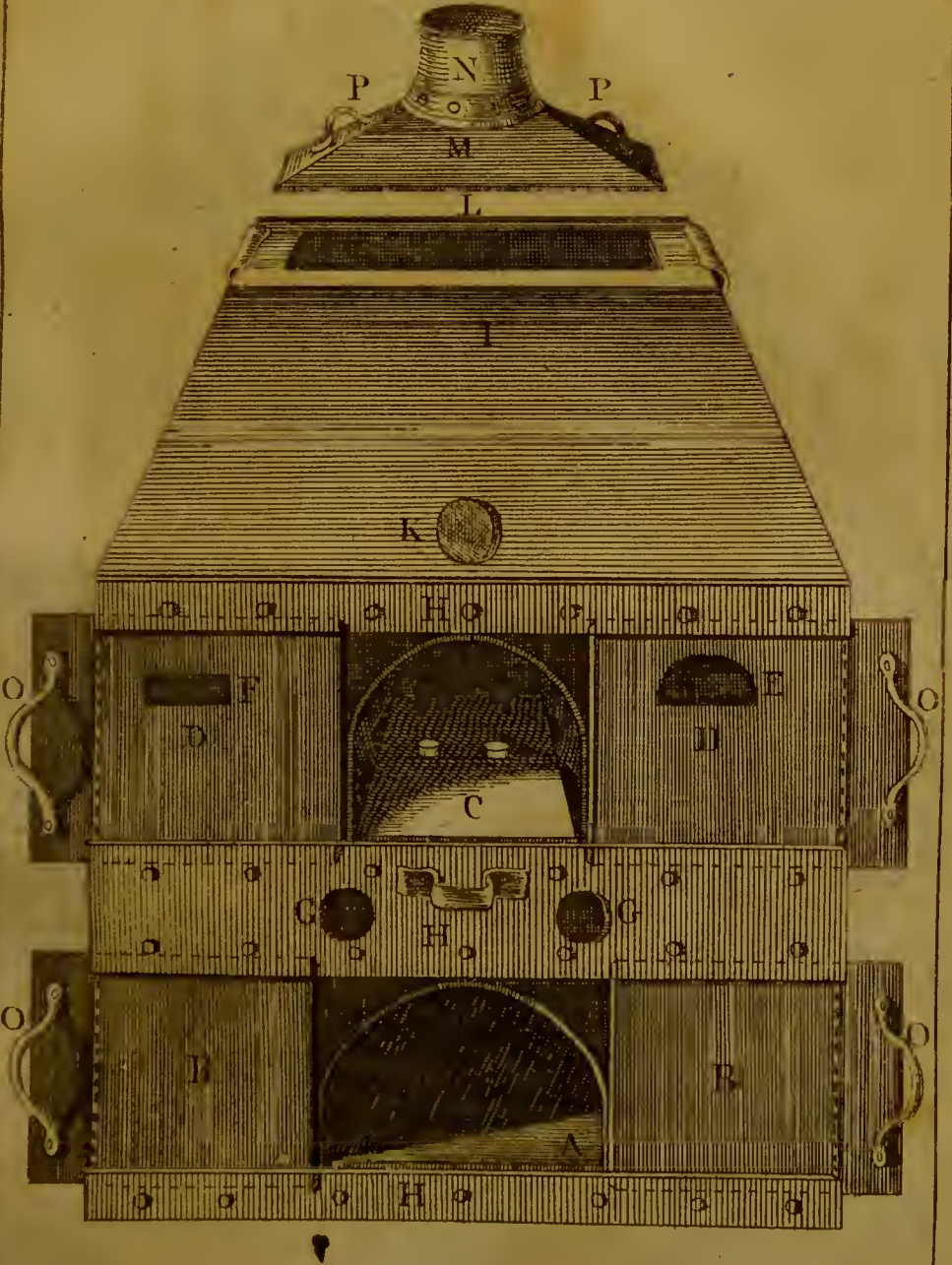


Fig. 4.









COMPARATIVE AFFINITIES  
*of sundry Substances.*

IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
			LC				
	Z <sub>e</sub>						

the Characters.

Copper

Iron

Lead

Tin

Z<sub>e</sub> Zinc

LC Calamine

Sulphur

Phlogiston

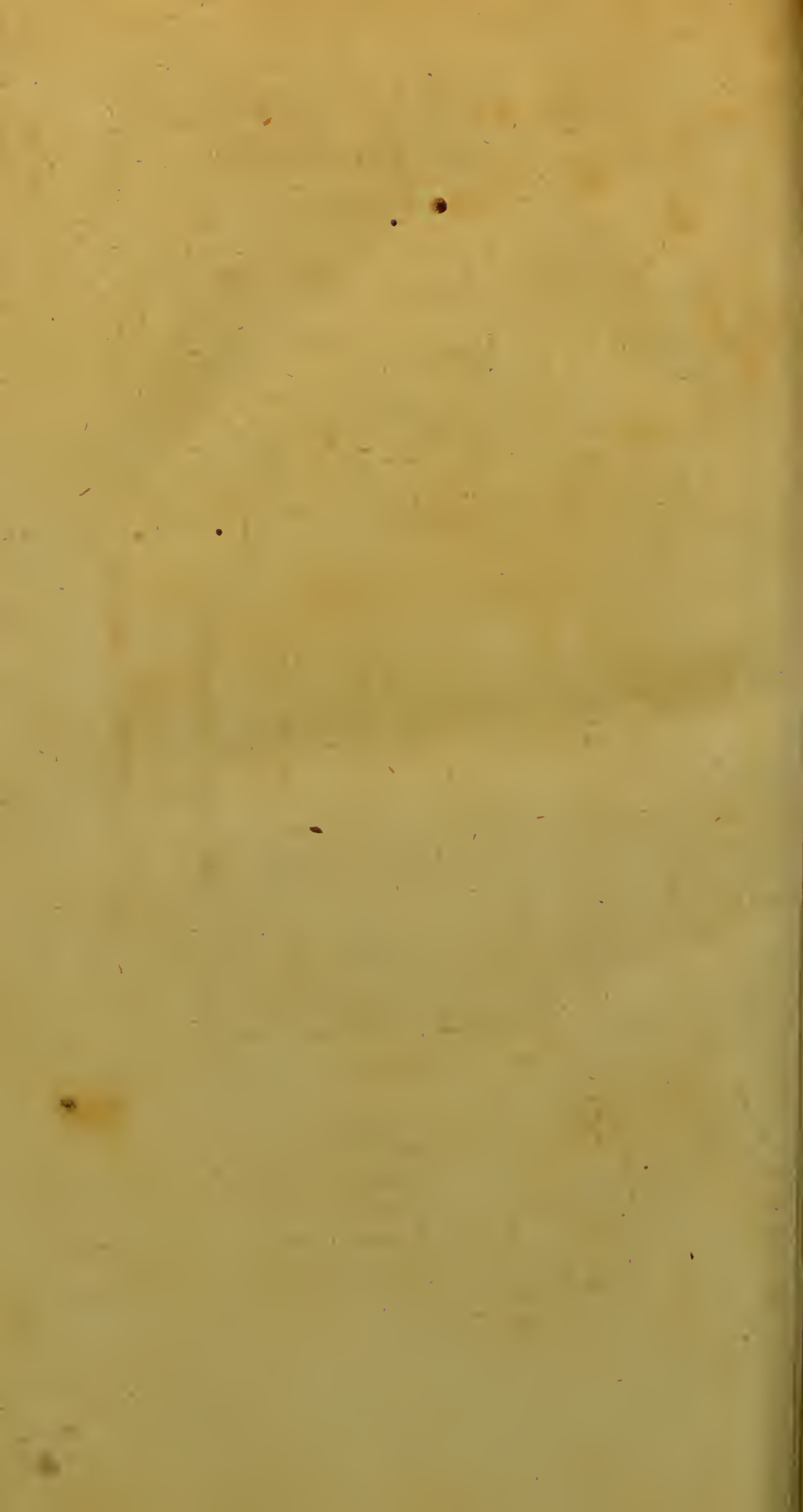
Spirit of Vinegar

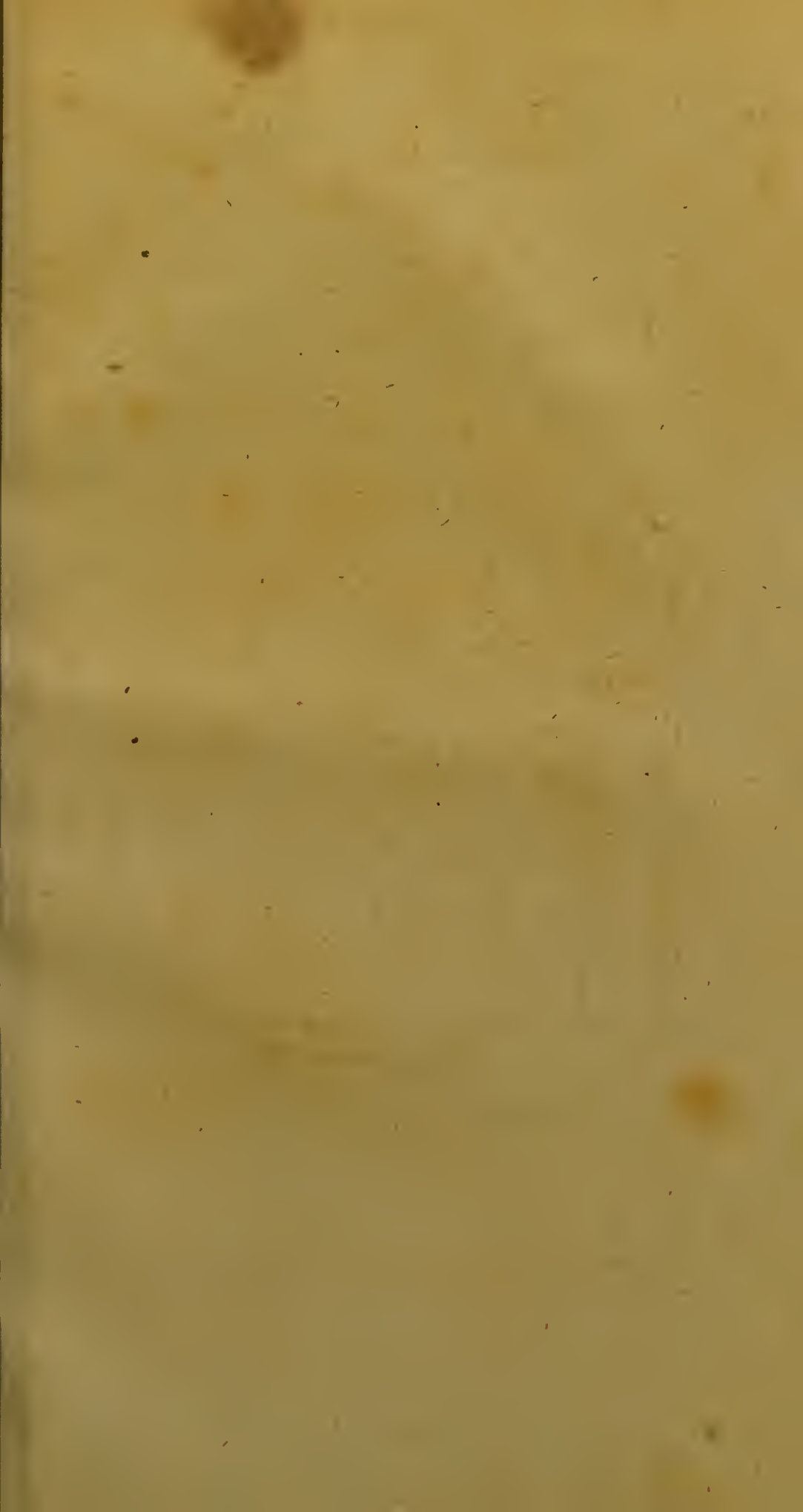
Water

Neutral Salts























Ardent Spirits.







*GEOFFROY'S TABLE of the  
observed between*

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	$\text{>}\ominus$	$\text{>}\oplus$	$\text{>}\oplus$		$\ominus\vee$	$\ominus^{\wedge}$	MS
$\ominus\vee$				$\text{>}\oplus$	$\text{>}\oplus$	$\text{>}\oplus$	$\text{>}\ominus$
$\ominus^{\wedge}$			$\ominus\vee$	$\text{>}\oplus$	$\text{>}\oplus$	$\text{>}\oplus$	$\text{>}\oplus$
			$\ominus^{\wedge}$	$\text{>}\ominus$	$\text{>}\ominus$	$\text{>}\ominus$	$\text{>}\oplus$
MS							
							
							
							
							

Explanation of

 *Acid Spirits*

$\text{>}\ominus$  *Marine Acid*

$\text{>}\oplus$  *Nitrous Acid*


$\text{>}\oplus$  *Vitriolic Acid*


$\ominus\vee$  *Fixed Alkali*

$\ominus^{\wedge}$  *Volatile Alkali*


 *Absorbent Earths*

MS *Metallic Substances*

 *Mercury*

 *Regulus of Antimony*

 *Gold*

 *Silver*













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$\frac{23}{4}$  29

